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Anatomical Studies on the Vascular System in the Petioles of Some Species of *Acer*, with Notes on the External Morphological Features*

By

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With 28 Figures in the Text

Introductory

For the purpose of gaining an accurate knowledge of the vascular system in the foliar organ of dicotyledonous plants and of the relationships existing between the various kinds of vascular systems and those between the vascular system in the petiolar organ and the external morphological characters of the leaves, the writer discussed the subjects in connexion with certain leguminous plants in his last paper (1934). In this paper, certain species of *Acer* that are abundant in Japan have been selected as suitable examples of palmate leaves. The writer will now describe with the same purpose in view, the vascular system in the petiolar organs of these species.

The presence of some sort of vascular system in the petioles of certain *Acer* species has already been reported by a number of investigators. The circular arrangement of the petiolar bundles in *Acer campestre* was reported by FRANK (1864), while C. DE CANDOLLE (1889) observed in some species, such as *A. macrophyllum*, *A. mexicanum*, *A. negundo* and *A. pseudo-platanus*, a single or a few medullary bundles inside a normal vascular ring consisting of several separated bundles. The presence of such medullary bundles was also reported by VAN TIEGHEM (*Acer* sp.) (1884) and PLITT (1886). PETIT (1889) also gave a brief description of the arrangement of petiolar bundles in some species of *Acer*. COL (1904), who observed three species of *Acer* in connexion with the arrangement of the petiolar bundles at a few different heights, especially with the origin of the nerves from the bundles at the petiolar top, wrote that, in *A. pseudo-platanus*, a single or a few medullary bundles were seen throughout the whole length of

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the petiole and the large palmate nerves; in *A. platanoides* the medullary bundles were found only at the petiolar top, while in *A. monspessulanum* such bundles were absent. On the external morphological features of the petiolar organ in this genus, however, so far as the writer is aware, the following passage from SOLEREDER (1899) seems to be the only description extant: „Der Blattbau ist bei allen bifazial mit Ausnahme von *A. Negundo*, dessen Blatt centrisch gebaut ist.“

Thus, although the vascular system of petioles in a number of species have hitherto been dealt with by the above-named authors, their descriptions and discussions mainly concerned the topographical aspects of the arrangement of the vascular bundles in transverse sections through a few definite heights of the petiole, for the reason that the intentions of these investigators were mainly to ascertain certain taxonomic features in the arrangements of the petiolar bundles. A few of them (e. g., COL), it is true have described whole vascular systems, but the number of species studied, at any rate, were too small to enable a general conclusion. The writer intends in the present investigation to observe the complete vascular system of the petiolar organ in a large number of species in order to obtain as complete an idea as possible of the vascular structure of the genus. In the first part of this paper, the vascular system of each species is described in detail, while in the second part, are general discussions on the types of vascular systems. Certain important histological and noteworthy external morphological characters are also treated.

The special terms used in this paper are mostly those that have been used in the writer's work on leguminous species (cf. 1934, p. 232). The new terms used in this paper will be explained as they appear in the text.

Material

The material used in the present study are mostly native to Japan proper, while some species from Formosa and some exotic species cultivated in the Botanic Garden of the Tokyo Imperial University have also been examined. The vascular systems were observed in the following manner: (1) The complete vascular system was observed, comparing at least, if possible, three leaves collected from different individuals; (2) in the examination, as far as possible, leaves of moderate size and of sufficient maturity were selected, large and small material being used only for reference; (3) material showing marked twisting in their petiolar bases, owing to their position on the branch, were not used in the present observation, since in such examples the construction of the vascular system in the petiolar base is usually asymmetric.

The following forty-two species were studied. The subdivision of the genus follows the system of KOIDZUMI (1911), who divided the genus into two subgenera, *Intrastaminalia* and *Extrastaminalia*, each subdivided into several sections (§). The Japanese names of these species are shown in parenthesis.

Subgn. A. *Intrastaminalia*§ 1. *Parviflora*

A. parviflorum FR. et SAV. (Tetsu-Kaede)

§ 2. *Indivisa*

A. distylum SIEB. et ZUCC. (Maruba-Kaede)

A. cratægifolium SIEB. et ZUCC. (Uri-Kaede)

§ 3. *Carpinifolia*

A. carpinifolium SIEB. et ZUCC. (Yamashiba-Kaede)

§ 4. *Macrantha*

A. rufinerve SIEB. et ZUCC. (Urihada-Kaede)

A. capillipes MAXIM. (Hosoe-Urihada)

A. rubescens HAYATA (Takasago-Urihada)

§ 5. *Palmatoidea*

A. micranthum SIEB. et ZUCC. (Ko-Mine-Kaede)

A. Tschonoskii MAXIM. (Mine-Kaede)

§ 6. *Arguta*

A. argutum MAXIM. (Asanoha-Kaede)

Subgn. B. *Extrastaminalia*§ 7. *Negundo*

A. negundo L. (Tonerikoba-no-Kaede)

§ 8. *Cissifolia*

A. cissifolium KOCH (Mitsude-Kaede)

§ 9. *Rubra*

A. pycnatum C. KOCH var. *rubrum* MAKINO (Hana-no-Ki)

A. dasycarpum EHRH. (*A. saccharinum* L.)

§ 10. *Spicata*

A. aizuiense NAKAI (Karakogi-Kaede)

A. trifidum HOOK. et ARN. (Toh-Kaede)

A. trifidum HOOK. et ARN. var. *formosanum* HAYATA (Takasago-Toh-Kaede)

A. ukurunduense TRAUTV. et MEY. (Ogara-Bana)

A. Oliverianum PAX var. *Nakaharæ* HAYATA (Shima-Momiji)

A. pseudo-platanus L.

§ 11. *Palmata*

A. amœnum CARR. (Oh-Momiji)

A. ornatum CARR. (Chirimen-Kaede)

- A. ornatum* CARR. var. *Matsumurae* KOIDZ. (Yama-Momiji)
A. formosum CARR. (Iroha-Momiji)
A. Sieboldianum MIQ. (Itaya-Meigetsu)
A. Sieboldianum MIQ. var. *microphyllum* MAXIM. (Ko-Hauchiwa-Kaede)
A. Shirasawanum KOIDZ. (Oh-Itaya-Meigetsu)
A. tenuifolium KOIDZ. (Hina-Uchiwa-Kaede)
A. japonicum THUNB. (Hauchiwa-Kaede)
A. Heyhachii MATSUM. (Mai-Kujaku)
- § 12. *Integrifolia*
A. oblongum WALL. (Kusunoha-Kaede)
A. laevigatum WALL.
- § 13. *Trifoliata*
A. nikoense MAXIM. (Megusuri-no-Ki)
- § 14. *Campestris*
A. campestre L.
- § 15. *Platanoidea*
A. mono MAXIM. (Itaya-Kaede)
A. mono MAXIM. var. *Paxii* HONDA (Oni-Itaya)
A. mono MAXIM. var. *dissectum* HONDA (Enkoh-Kaede)
A. mono MAXIM. var. *nikkoense* HONDA (Urage-Enkoh-Kaede)
A. mono MAXIM. var. *velutinum* NAKAI (Ezo-Itaya)
A. Mayri G. V. SCHWERIN (Akame-Itaya)
A. Miyabei MAXIM. (Kurobi-Itaya)
- § 16. *Diabolica*
A. diabolicum BLUME (Oni-Momiji)

To my regret, species belonging to § *Glabra*, § *Lithocarpa* and § *Saccharina* were not examined in the present study.

Technique

In tracing the vascular system, serial free hand sections or, rarely, those made with the aid of a sliding-microtome were used, and the figures in every case drawn from the leaf-base to the petiolar top by means of ABBE's camera-lucida. In mounting these sections on slides, the 'agar-method' that I used in my study of leguminous leaves (1934) gave excellent results. The methods used will now be briefly described with some remarks on staining. Two per cent agar-gel seems most suitable for this purpose. Immediately before mounting the sections, a little agar-gel, which is put into a small glass bottle and immersed in a hot-water-bath, is heated on the flame of a burner to obtain the agar-solution. A suitable quantity of the agar-solution thus made is then

laid on a cleaned slide glass in stripes with a fine brush, on which slide glass the sections from fresh or alcoholic material are arranged in the order required. The slide glass on which the sections are fixed is immersed for from 5 to 10 minutes respectively in a series of alcohols (50, 75, 95 and 100 per cent strengths) in order to dehydrate the agar-stripe. With this treatment the sections are fixed firmly on the slide glass. The sections on the slide glass are stained overnight in dilute safranin solution (50 per cent alcoholic), then rinsed in 50, 75 and 95 per cent alcohols until the stain in the cellulose walls is reduced to a light pink colour. After transferring the sections to 100 per cent alcohol, they are stained for a few minutes in a solution of light green (1 gr. in 100 c.c. of absolute alcohol). The stain acts not only on the sections, but also slightly on the agar-agar, but the latter may be decoloured by immersing them in absolute alcohol for from half an hour to an hour. They are then transferred to xylol after being passed through a mixture of equal parts of xylol and absolute alcohol, each for from 5 to 10 minutes, and finally mounted in Canada balsam.

I. Detailed Descriptions of the Vascular System of Each Species

Subgn. A. INTRASTAMINALIA

§ 1. *PARVIFLORA*

Acer parviflorum FR. et SAV. [Figs. 1, 2]. Leaves palmately 5-lobed. In the vascular cylinder of the stem, just below the node, are distinguishable six foliar traces nearly equal in size, each three of the two sets (M_1 , L_1 , L_1' and M_2 , L_2 , L_2') enter one of the opposite leaves. It will easily be seen that the foliar traces consist of crowded radial rows of vessels of rather small diameter, while in the other part of the vascular cylinder of the stem the vessels are usually large and somewhat scattered (Fig. 1, A). The median traces M_1 and M_2 in this figure already leave the vascular cylinder, while the lateral traces (L_1 , L_1' and L_2 , L_2') are still arranged on the stem cylinder. At a little higher part of the node, where the numerous branch traces issue forth, the lateral traces emerge from the vascular cylinder of the stem and each soon divides into two (Fig. 1, B). The median trace then divides into three—a smaller median and a pair of larger laterals (Fig. 1, B, and Fig. 2, A)—each of the latter soon dividing again into two. Thus five bundles, almost alike in size (m , m_1 , m_1' , v_1 and v_1'),

are arranged in a circle, while at the same time, two pairs of lateral bundles subdivide to form four groups of bundles arranged also each on a circle; the components $v_1, v_1', v_2, v_2', v_3, v_3', v_4, v_4', v_5$ and v_5' of the ventral bundle, being situated on the ventral of these circles (Fig. 2, B). A little higher up, these circles approach each other to form a crescent, on the chord of which the components of the ventral bundle are arranged (Fig. 2, C). The chord bundles and those on the dorsal arc are so situated as to face their respective xylems. A little higher up, where the ventral furrow of the petiolar base be-

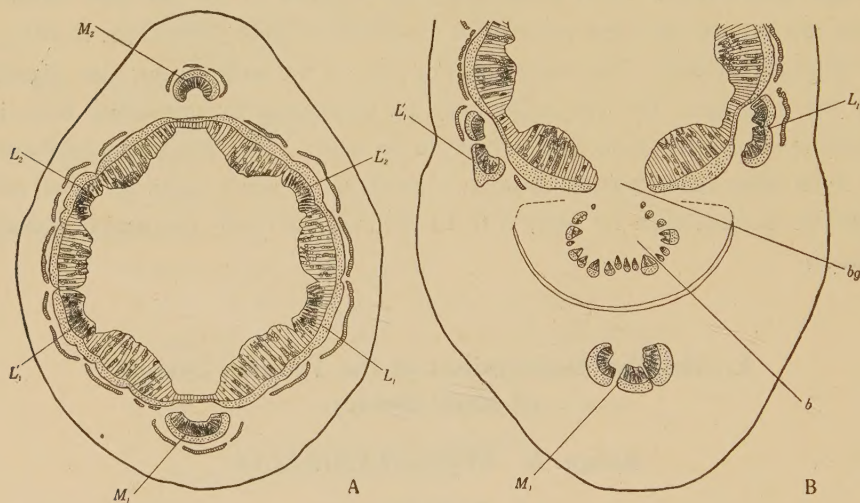


Fig. 1. *A. parviflorum* (A, B, $\times 12$): Two successive sections of a node of stem. A, six foliar traces, M_1, L_1, L_1' and M_2, L_2, L_2' , are seen, the former three and latter three traces being supplied to the opposite leaves of the node. The median traces, M_1 and M_2 , have left the vascular cylinder. B, height immediately above that in A; the median trace M_1 has just divided into three; lateral traces, L_1 and L_1' , are going to divide into two; the vascular circle of the axillary bud has formed. *b*, axillary bud; *bg*, branch gap.

comes nearly indistinct and the outline of the section shows nearly a circle, are usually eleven bundles on the dorsal arc, namely, $m, m_1, m_1', l_1, l_1', l_2, l_2', l_3, l_3', l_4$ and l_4' , of which m, m_1 and m_1' have their origin in the original median trace; l_3, l_4 and l_3', l_4' in the outer halves of the lateral traces, and l_1, l_2 and l_1', l_2' in the inner halves (Fig. 2, E); while in the figure the chord bundles are partially fused to form three larger ones, namely, $v_2 + v_1 + v_1' + v_2', v_3 + v_4 + v_5$ and $v_3' + v_4' + v_5'$. Here, the medullary bundles form simultaneously. Since the formation and special structure of the medullary bundles will be dealt with in

detail later (cf. pp. 50–51), only a brief description of them will be given here. As soon as the components of the ventral bundle migrate to the ventral side,

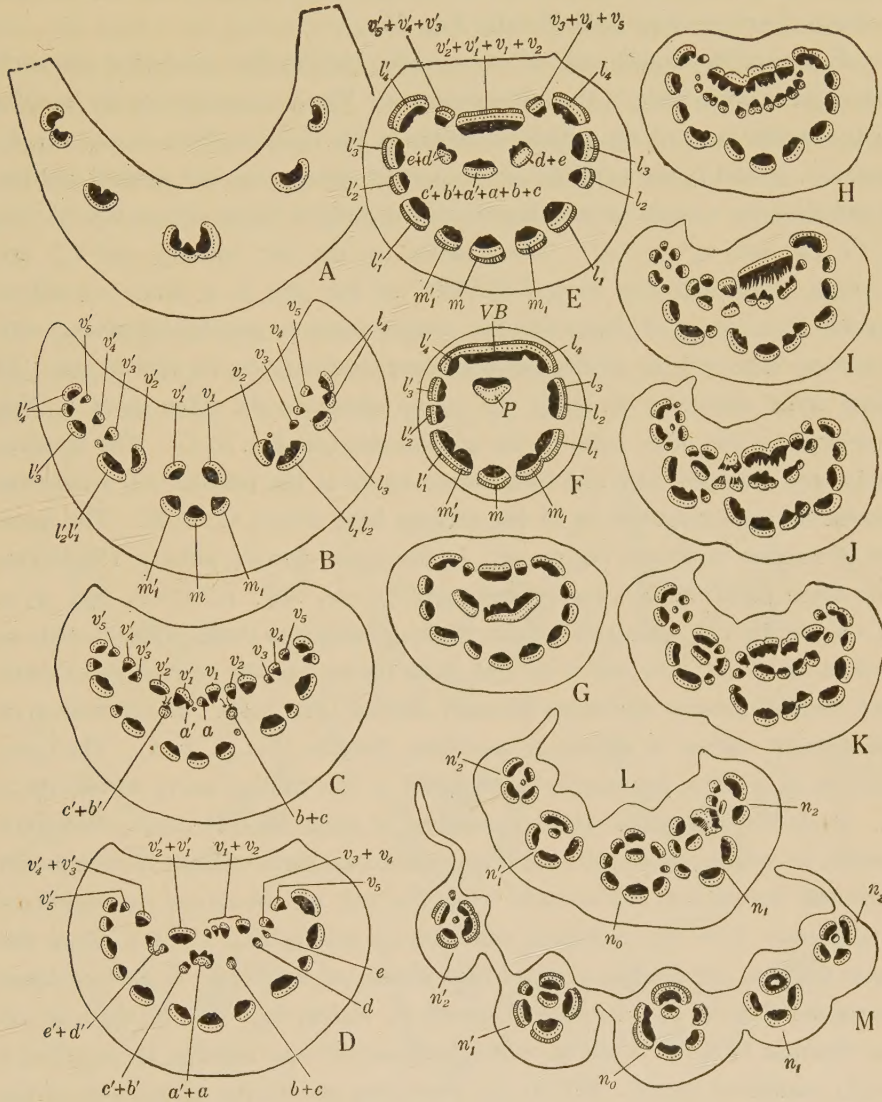


Fig. 2. *A. parviflorum* (A–M, $\times 9$): A–E, successive sections of petiolar base; F, middle of petiole; H–M, successive heights of petiolar top and lamina base. Solid black, xylem; dotted, phloem; shaded, mechanical tissue.

the small bundles a , b and a' , b' detach themselves from both margins of v_1 and v'_1 ; c , c' and d , d' from v_2 and v'_2 ; e and e' from the inner margins of

v_3 and v_3' (Fig. 2, C, D).¹⁾ Immediately after a and a' , b and c , b' and c' , d and e , d' and e' are respectively fused to form the bundles $a+a'$, $b+c$, $d+e$, $b'+c'$, $d'+e'$, of which $a+a'$, $b+c$, $b'+c'$ further fuse to form a large bundle $c+b+a+a'+b'+c'$ (Fig. 2, D, E; also Fig. 24).

Entering the slender part of the petiole, the bundles gradually approach one another when some of them fuse together. The arrangement of the bundles in the middle part of the petiole is shown in Fig. 2, F, in which l_1 and m_1 , l_1' and m_1' , l_2 and l_3 are partially or completely fused, and the ventral portion is occupied by a large ventral bundle VB , namely a fusion of $v_2+v_1+v_1'+v_2'$, $v_3+v_4+v_5$ and $v_3'+v_4'+v_5'$. The bundles on the arc ends (l_4 and l_4') are partially fused with the ventral bundle. In the pith is a single medullary bundle P , a fusion of three bundles, which shows a peculiar structure with a phloem ring and the xylem elements developed only on its ventral side. In some other examples, however, the xylem elements are often more or less developed on the other sides of the phloem ring (see Fig. 23, C). The bundles, which are diverged, fuse and then diverge again at the petiolar top presenting almost the same condition as in the petiolar base (Fig. 2, G; cf. E). The number of bundles on the arc (m , m_1 , m_1' , l_1 , etc.) again become eleven; VB divides into three parts nearly proportional to $v_2+v_1+v_1'+v_2'$, $v_3+v_4+v_5$ and $v_3'+v_4'+v_5'$, while the medullary bundle P also divides into three, proportionally to $c+b+a+a'+b'+c'$, $d+e$ and $d'+e'$. A little higher up, the ventral and medullary bundles become numerous through division (Fig. 2, H). The formation of the palmate nerves is shown in successive heights (Fig. 2, I-M). The composition of a nerve is typically represented in the median nerve n_0 in Fig. 2, L. There are a vascular circle consisting of eight bundles and a medullary bundle, of which the ventral three and the dorsal three respectively originated from the ventral and arc bundles, while the pair of laterals and the medullary bundle came from the medullary bundle in the petiole (Fig. 2, H-K). Since the three bundles, on the lateral sides fuse sooner or later into a pair of large lateral bundles, as may be seen in nerves n_1 and n_2 in Fig. 2, M, there are on the vascular circle of a nerve, as a whole, usually four bundles, surrounding a single medullary bundle. But in the outermost nerves, the composition of the vascular circle slightly differs in that the lateral bundle on the outer side of these four contains no parts that were derived from the ventral bundle or from the

1) The bundles a , a' , b , etc. are not always single bundles, but often consist of a few minute ones that successively issue from the mother bundle.

medullary bundle, but only the segment on the extreme ends of the dorsal arc. The ends of the ventral bundles of a nerve and the medullary bundle often fuse together to form a ringlet with an inner xylem (n_1 in Fig. 2, M). At a higher position, the lateral and dorsal bundles in each circle usually fuse into a dorsal arc.

Considering the relationship between the original foliar traces and the constitution of the palmate nerves, the median nerve n_0 is continuous with the original median foliar trace; the n_2 and n_2' continuous with the lateral traces, and although n_1 and n_1' are chiefly continuous with the lateral traces, a small part of the median trace joins each of the two vascular circles of n_1 and n_1' .

§ 2. INDIVISA

Acer distylum SIEB. et ZUCC. [Fig. 3]. Leaves simple, cordate at the lamina base with 7, rarely 9, palmate nerves that abruptly diminish in size from the median to the outer. Three foliar traces, all nearly alike in size, arise from

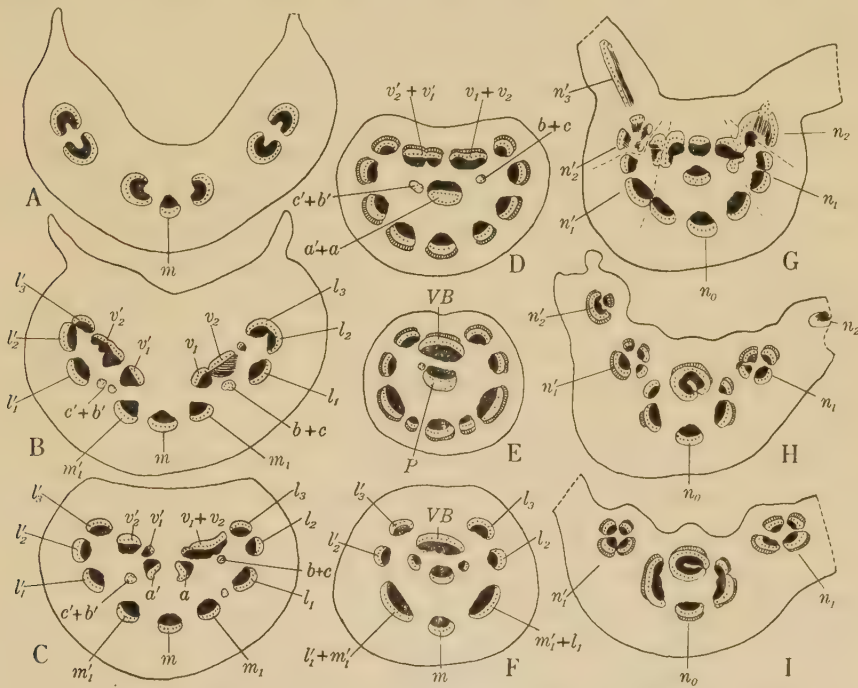


Fig. 3. *A. distylum* (A-I, $\times 10$): A-D, petiolar base; E, middle of petiole; F-I, petiolar top and lamina base.

the trilacunar node. At the petiolar base, the median foliar trace divides at first into three bundles, a median m and a pair of large laterals (Fig. 3, A),

the latter of which soon divide into two, m_1 , v_1 and m_1' , v_1' , (Fig. 3, B). Each lateral trace divides at first into two (Fig. 3, A), then each of these halves again divide into two, l_1 , l_2 , l_3 , v_2 and l_1' , l_2' , l_3' , v_2' (Fig. 3, B). Higher in the petiolar base, these bundles are arranged in a crescent. Bundles v_1 , v_1' , v_2 and v_2' , which soon fuse into two bundles (v_1+v_2 and $v_1'+v_2'$), are situated on the chord, and the others l_1 , l_1' , l_2 , l_2' , l_3 and l_3' on the arc of a crescent (Fig. 3, C, D). Meanwhile a medullary bundle forms in the same manner as that of *A. parviflorum*, that is, from the margin of v_1 and v_1' near the median plane arises a comparatively large bundle a and a' , which twisting 180° while they migrate into the pith, are fused side by side into one bundle $a+a'$ (Fig. 3, C). From the other end of v_1 and v_1' , small bundles b and b' , and from the median margins of v_2 and v_2' , further small bundles c and c' , pass into the pith which are soon fused to form a pair of small medullary bundles $b+c$ and $b'+c'$ (Fig. 3, B-D). In the slender part of the petiole is a circle of vascular bundles in which is enclosed a medullary bundle (Fig. 3, E: middle of petiole). A large ventral bundle VB is formed by the fusion of v_1+v_2 and $v_1'+v_2'$; l_1 and a half of m_1 , l_1' and a half of m_1' fuse together, while the remaining half of m_1 and m_1' also fuse with the former higher up into m_1+l_1 and $m_1'+l_1'$ (Fig. 3, F). A medullary bundle P is formed by the fusion of $a+a'$, $b+c$ and $b'+c'$.¹⁾ The manner in which the palmate nerves form is almost the same, especially in the composition of the vascular circle of each nerve, as in the case of *A. parviflorum*, although the medullary bundle behaves somewhat differently (Fig. 3, F-I). Near the petiolar top the medullary bundle is divided into a large median and two small laterals (Fig. 3, F), of which the median one enters the circle of the median nerve n_0 , while the two laterals again divide into two and enter the lateral sides of n_0 and the median sides of n_1 and n_1' (Fig. 3, G). Thus the medullary bundle is seen only in the median nerve, in which its end soon fuses with the end of the ventral bundle to form a ringlet as was observed in *A. parviflorum* (Fig. 3, I).

***Acer crataegifolium* SIEB. et ZUCC.** [Fig. 4]. Leaves palmately 3-lobed or often almost simple, provided with three palmate nerves. At the base of the petiole, the median foliar trace is divided into five bundles m , m_1 , m_1' , v_1 and v_1' , in which m_1 and m_1' are slightly smaller than the others; while each of a pair of comparatively small lateral ones divides into three, l_1 , l_2 , v_2 and l_1' , l_2' , v_2' (Fig. 4, A). There are no medullary bundles. In the slender part of the

1) Structure of medullary bundle same as that in *A. parviflorum* (cf. p. 8).

petiole, vascular bundles are arranged in the form of a crescent: a large ventral bundle *VB* formed by the fusion of v_1 , v_2 , v_1' and v_2' , is on the chord, while a median bundle *m*, and a couple of pairs of lateral bundles m_1+l_1 , $m_1'+l_1'$, l_2 and l_2' , are arranged on the arc of the crescent (Fig. 4, B: middle of petiole).¹⁾ At the petiolar top, m_1+l_1 and $m_1'+l_1'$ are divided into two parts almost alike in size, while *VB* is divided into a large median and a pair of small laterals (Fig. 4, C). The vascular circle of the median nerve n_0 consists of *m*, a half each of m_1+l_1 and $m_1'+l_1'$, and the median part of *VB*. As in the case of examples already given, the median part of *VB* is again divided into three, the laterals of each of which are fused with each inner half of m_1+l_1 and $m_1'+l_1'$ to form a pair of large lateral bundles of the vascular circle of n_0 (Fig. 4, E, F). In the vascular circle of the lateral nerve n_1 or n_1' ,

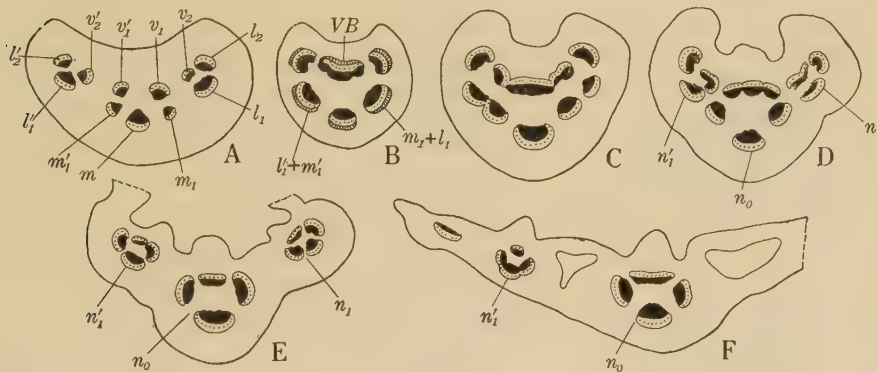


Fig. 4. *A. crataegifolium* (A-F, $\times 15$): A, petiolar base; B, middle of petiole; C-D, successive heights of petiolar top and lamina base.

one of the large lateral bundles is formed by l_2 or l_2' and the other by fusion of a part of a half of m_1+l_1 or $m_1'+l_1'$ and half of the lateral segment of *VB* (Fig. 4, D, E).

§ 3. *CARPINIFOLIA*

***Acer carpinifolium* SIEB. et ZUCC.** [Fig. 5]. Simple leaves with pinnate nerves, provided with a short petiole. At the petiolar base, bundles v_1 , v_2 , v_1' and v_2' are arranged on the chord of the vascular crescent as in the former examples. They are soon fused into a pair of ventral bundles v_1+v_2 and

1) The bundles on the two extremities of the arc l_2 and l_2' are, rarely, either amphivasal concentric or crescentic (cf. p. 46).

$v_1' + v_2'$ (Fig. 5, A, B), which run separated throughout the whole course of the petiole, fusing into a ventral bundle *VB* only in lower part of the midrib (Fig.

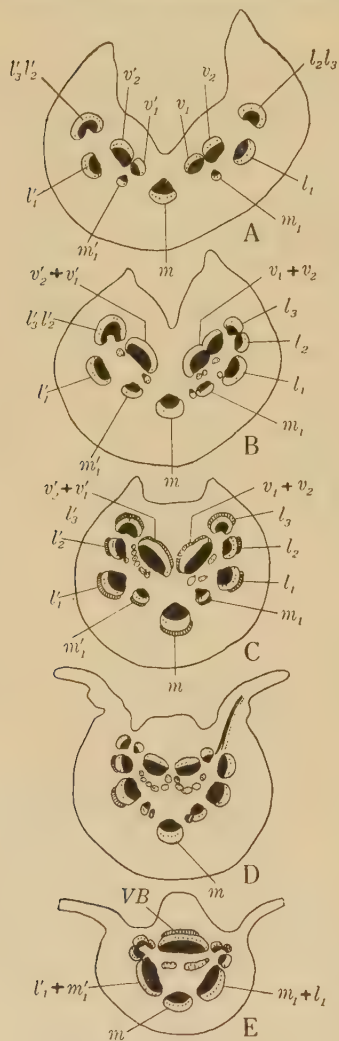


Fig. 5. *A. carpinifolium* (A-E, $\times 15$): A, B, petiolar base; C, middle of petiole; D, lamina base; E, lower height of lamina midrib.

5, C-E). Of the arc bundles, median bundle *m* and a pair of small laterals m_1 and m_1' have their origin in the median trace, and the other laterals l_1 , l_2 , l_3 and l_1' , l_2' , l_3' in the lateral traces; these bundles remaining separately throughout the whole length of the short petiole (Fig. 5, C: middle of petiole). In the midrib, however, m_1 and l_1 , m_1' and l_1' are respectively fused to form a pair of large lateral bundles $m_1 + l_1$ and $m_1' + l_1'$ (Fig. 5, E). At the same time the medullary bundles form, which in the example illustrated here, begin at a certain height of the petiolar base (Fig. 5, B). Several minute fascicles consisting mostly of phloem elements, and which form successively from both ends of the ventral bundles $v_1 + v_2$ and $v_1' + v_2'$, migrate along the protoxylem side of their mother bundles. These fascicles join with a few minute ones that have formed from a few of the bundles on the arc and possess the same attributes as the former to form a pair of groups of medullary bundles, each arranged on a small arc (Fig. 5, B-D). In the midrib of the lamina they are fused into a small number of medullary bundles (Fig. 5, E). In some other examples, the medullary bundles begin to form at the middle, higher up, or at the extreme end of the petiole. The number of medullary bundles varies also to a certain extent.

§ 4. *MACRANTHA*

Acer rufinerve SIEB. et ZUCC. [Fig. 6, A-H]. Leaves 3 to 5-lobed, with conspicuous 3 palmate nerves: trilacunar. Each lateral foliar trace is divided

into two when it leaves the foliar gap, soon after which the median trace is divided into three (Fig. 6, A). Then at a lower part of the petiolar base the outer pair of bundles are again divided into two, with the result that three pairs of bundles l_1 , l_1' , l_2 , l_2' and l_3 , l_3' are derived from the lateral foliar traces. At the same time, each lateral bundle derived from the median foliar



Fig. 6. *A. rufinerve* (A-H, $\times 12$): A-C, petiolar base; D, middle of petiole; E-N, petiolar top and lamina base; D, middle of petiole; E-N, petiolar top and lamina base. *A. capillipes* (I-K, $\times 18$): I, middle of petiole; J, K, petiolar top. *A. rubescens* (L-N, $\times 15$): L, middle of petiole; M, N, petiolar top.

trace is divided into a small bundle m_1 or m_1' and a component of the ventral bundle v_1 or v_1' (Fig. 6, B). Higher in the petiolar base, a pair of small bundles x and x' are respectively segmented from l_1 and l_1' and situated between l_1 and l_2 , and l_1' and l_2' . Then v_1 and v_1' are fused into a single large ventral

bundle VB , which is, therefore, formed from the original median trace alone (Fig. 6, C). Soon after this, m_1 and m_1' are respectively fused with l_1 and l_1' to form m_1+l_1 and $m_1'+l_1'$. The same condition continues throughout almost the whole length of the slender part (Fig. 6, D: middle of petiole),^{1),2)} Near the petiolar top, small bundles x and x' on the arc enter the pith to become medullary (Fig. 6, E).³⁾ The formation of the vascular circle of the palmate nerves shows great similarity to *A. distylum*, but all the medullary bundles x and x' insert into the lateral sides of the vascular circle of the nerves n_0 , n_1 and n_1' , showing no medullary position in any of the nerves (Fig. 6, F-H).

In another example a minute part of each or one of the lateral foliar traces is found to participate in the formation of the ventral bundle, which however seems to be of rare occurrence.

***Acer capillipes* MAXIM.** [Fig. 6, I-K]. Leaves 3 (rarely 5)-lobed, with 5 palmate nerves in which the outer laterals are exceedingly small. The whole vascular system greatly resembles the usual case of *A. rufinerve* (Fig. 6, I: middle of petiole). So far as our present observation went, the small bundles corresponding to x and x' in the former species have never been seen in its slender part, although at the petiolar top they may be seen from the dorsal arc to the pith, the part of the departure exactly corresponding to the case of *A. rufinerve* (Fig. 6, J and K). The other conditions in the petiolar top are the same as in that of *A. rufinerve*.

***Acer rubescens* HAYATA** [Fig. 6, L-N]. Leaves similar to the former species. The vascular system in the petiolar base and the slender part is the same as that in *A. capillipes*.⁴⁾ In its slender part may be seen a pair of small bundles x and x' (Fig. 6, L: middle of petiole). At the petiolar top, several minute medullary bundles are formed, not only from x and x' , but also from other arc bundles near the end of the arc and a few portions of the ventral bundles (Fig. 6, M, N). At the time of the formation of the vascular circle of the nerves, a part of these medullary bundles enters the lateral side, and another part into the ventral side, but there are no medullary bundles in any of the nerves.

1) The bundles on the extremity of the arc of the vascular crescent often show concentric and other interesting structures, all of which are treated in detail in a later part of this paper (pp. 45-47, and Figs. 20, 21, 22). The structure of the median bundle on the dorsal arc is shown on pp. 43-44 and Fig. 18.

2) Although small bundles of phloem elements alone often branch off from one or both of l_3 and l_3' to the outer margin, they end blindly higher up in the slender part.

3) Structure of medullary bundle shown in p. 54 and Fig. 25, A.

4) Differing from *A. rufinerve* or *A. capillipes*, no bundles with concentric structure were ever observed during these observations.

§ 5. *PALMATOIDEA*

Acer micranthum SIEB. et ZUCC. [Fig. 7, A-D]. Leaves palmately 5-lobed. The whole vascular system shows marked resemblance to that in a species of § *Macrantha*. The ventral bundle *VB* is formed by the fusion of v_1 and v_1' derived from the original median foliar trace; in the illustrated example a very minute part of the lateral foliar trace joins it as a rare case. Since the lateral bundles derived from the median foliar trace (m_1, m_1' in the preceding descrip-

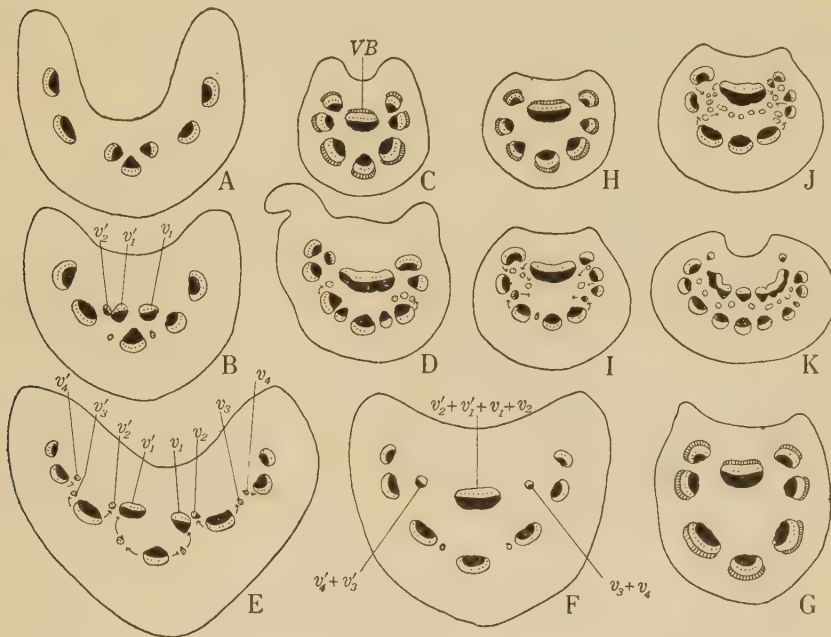


Fig. 7. *A. micranthum* (A-D, $\times 20$): A, B, petiolar base; C, middle of petiole; D, petiolar top. *A. Tschonoskii* (E-G, $\times 15$): E, F, petiolar base; G, middle of petiole. *A. argutum* (H-K, $\times 15$): H, middle of petiole; I-K, petiolar top.

tion, e. g., in *A. rufinerve*) are usually very small and frequently altogether absent (Fig. 7, A, B), three pairs of lateral bundles have their origin in the lateral foliar traces, the median and ventral bundles, and in the median trace (Fig. 7, C: middle of petiole). The way in which the medullary bundles form at the petiolar top is exactly the same as in *A. capillipes* (Fig. 7, D; cf. Fig. 6, J, K). In one example a minute bundle arises from the median bundle. No peculiarities are found in the formation of the vascular circle of the palmate nerves.

Acer Tschonoskii MAXIM. [Fig. 7, E-G]. Leaves palmately 5-lobed. At the petiolar base, after the median and lateral foliar traces have divided respectively into five (a median, a pair of very small laterals, v_1 and v_1') and two bundles as in the case of *A. micranthum* (cf. Fig. 7, A), small bundles v_2 , v_2' , v_3 , v_3' , v_4 and v_4' branch off from bundles derived from the original lateral foliar traces (Fig. 7, E). The ventral bundle is formed by the fusion of v_1 , v_1' , v_2 , v_2' , v_3 , v_3' , v_4 and v_4' (Fig. 7, F, G: G, middle of petiole). Of the components of the ventral bundle, v_1 and v_1' are very large compared with v_2 , v_2' , etc., some of the latter being often wanting; in an extreme case they were altogether absent. The vascular system in the slender part and the petiolar top is the same as that in *A. micranthum*.

§ 6. ARGUTA

Acer argutum MAXIM. [Fig. 7, H-K]. Leaves 5-lobed. The ventral bundle in the petiolar base forms in the same manner as that of *A. crataegifolium*, while the lateral bundles from the original median foliar trace is altogether lacking, or, if present, very minute. There are three pairs of lateral bundles which have their origin in the lateral traces (Fig. 7, H: middle of petiole). The medullary bundles in the petiolar top are fairly numerous and occur from all the lateral bundles, in which the parts from which they depart are indicated in Fig. 7 by arrows (I and J). In a short while, these medullary bundles arrange themselves in an arc (Fig. 7, K) and enter the ventral and lateral parts of every vascular circle of nerves.

Subgn. B. EXTRASTAMINALIA

§ 7. NEGUNDO

Acer negundo L. [Fig. 8]. Leaves pinnately 3 to 5-foliolate, provided by long petiole. In a 5-foliolate leaf, as shown in Fig. 8, H, the vascular circle higher up in the petiolar base consists of a median bundle m , lateral bundles m_1 , m_1' , l_1 , l_1' , x , x' , l_2 , l_2' , l_3 , l_3' and a large ventral bundle VB . There are besides a few medullary bundles arranged in an arc. Although the vascular circle is formed in nearly the same way as in *A. parviflorum* (Fig. 8, A-G; cf. Fig. 2, A-E), the medullary bundles are more complex than in the latter species, that is, a large part of them have originated from the components of the ventral bundle although a few arose from the bundles on the dorsal arc Fig. 8, D-F).¹⁾

1) In these figures the origin of the medullary bundles are indicated by arrows.

These bundles that have arisen in the manner mentioned are arranged in an arc and then fused into a large medullary bundle in a slender part of the petiole



Fig. 8. *A. negundo* (A-Q, $\times 8$): A-H, petiolar base; I, middle of petiole; J-O, successive sections of 1st nodule; P, middle of 1st internode; Q, middle of petiolule of terminal leaflet.

(Fig. 8, G, H, I). In some examples, however, some of them, particularly those situated on the lateral side of the medullary arc, remain separated throughout

the whole slender part of the petiole, where l_a , l_a' and the ventral bundle VB become continuous (Fig. 8, I: middle of petiole).

Just below the first nodule (or petiolar top), the vascular system is divided into three parts, both laterals of which supply the lateral leaflets, while the median part enters the rachis. The manner in which the vascular circle and the medullary bundles form is almost the same as that of *A. parviflorum*, but the circle consists of a ventral bundle and a dorsal arc of from seven to nine bundles, while the behaviour of the medullary bundles is somewhat more complicated in that they form at the nodule a circular arrangement and then divide into three parts for the rachis and both lateral leaflets (Fig. 8, J-O). The bundles x and x' in the slender part (Fig. 8, I) join with the medullary bundles of the lateral leaflets. In the petiolule of each leaflet, the medullary and ventral bundles are apt to fuse into a continuous ringlet as was observed in *A. parviflorum* and *A. distylum* (Fig. 8, O). Although the arrangement of the vascular bundles in the first internode is almost the same as that in the slender part of the petiole, there are frequently several medullary bundles (Fig. 8, P: middle of first internode). At the second nodule the vascular supply for the lateral pinnæ occurs in the same manner as in that of the first (Fig. 8, Q: middle of petiolule of the terminal leaflet).

§ 8. *CISSIFOLIA*

Acer cissifolium KOCH [Fig. 9, A, B]. Leaves palmately trifoliolate.¹⁾ The vascular circle in the slender part of the petiole forms in the same manner as that of *A. crataegifolium*, and a single medullary bundle forms in the same manner as in *A. distylum* (Fig. 9, A: middle of petiole). The constitution of the vascular circle in each petiolule is also the same as that of the three palmate nerves of *A. crataegifolium*, but there is in each circle a single small medullary bundle which has its origin in the medullary bundle in the slender part (Fig. 9, B: three palmate petiolules have just separated).

§ 9. *RUBRA*

Acer pycnatum KOCH var. *rubrum* MAKINO [Fig. 9, C]. Leaves palmately 3-lobed. Although in the type of leaves it differs from *A. cissifolium*, the whole vascular system in the slender part and top of petiole shows great similarity (Fig. 9, B: middle of petiole).²⁾ In the petiolar base, however, the components

1) Leaves on the shoot rarely pedately 5-foliolate as an abnormal form.

2) The structure of a medullary bundle is illustrated in Fig. 23, A; also see p. 48 sqq.

of the ventral bundle from the lateral foliar trace are fairly small compared with those from the median trace. In an exceptional example, I found a case without medullary bundles in any part of the whole vascular system.

A. dasycarpum EHRR. (*A. saccharinum* L.) [Fig. 9, D-I]. Leaves palmately 5-lobed. Although the vascular system represents almost the same condition as that of *A. cissifolium*, the medullary bundles usually form in a very complicated manner as in *A. negundo*. In Fig. 9 (D-F), v_1 , v_1' and v_2 , v_2' are the

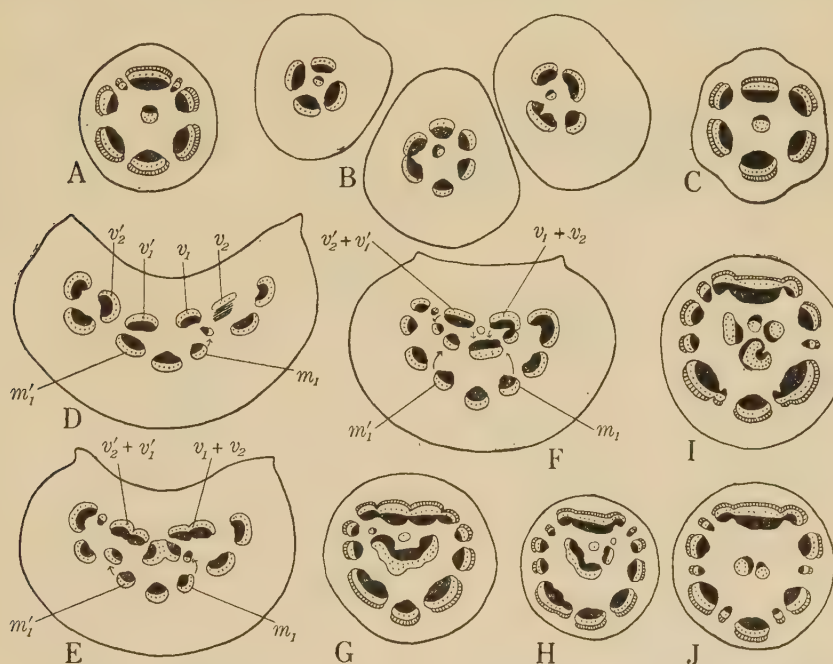


Fig. 9. *A. cissifolium* (A, B, $\times 20$): A, middle of petiole; B, base of three palmate petiolules. *A. pycnatum* var. *rubrum* (C, $\times 15$): middle of petiole. *A. dasycarpum* (D-I, $\times 12$): D-G, petiolar base; H-J, middles of three different petioles.

ventral component bundles in the slender part of the petiole, of which the former and latter are respectively derived from the median and lateral traces. As indicated by arrows, the medullary bundles arise not only from these ventral bundles, but also from the dorsal arc. The number and arrangement of medullary bundles in the slender part of the petiole are very diverse. In some of the examples they are fused into a single large bundle, but in many of them they are disposed either in arc fashion or irregularly (Fig. 9, G-J: H, I, J are middles of the petiole from three different examples). After anastomosing with one another through the slender part of the petiole, these medullary bundles arrange

themselves at the petiolar top in an arc. Each vascular circle of the palmate nerves form in the same way as in *A. parviflorum*. A single medullary bundle is seen in each nerve.

§ 10. *SPICATA*

***Acer aizuense* NAKAI** [Fig. 10, A]. Leaves palmately 3-lobed, but frequently almost simple; provided in many cases with somewhat conspicuous three palmate nerves. Whole vascular system similar to that of *A. crataegifolium* (Fig. 10, A: middle of petiole). No medullary bundles found.

***Acer trifidum* HOOK. et ARN.** [Fig. 10, B]. Leaves palmately 3-lobed. The vascular system in the petiolar base and the slender part are similar to that in *A. crataegifolium* (Fig. 10, B: middle of petiole). In the petiolar top are often found a few minute medullary bundles which behave as those in *A. rufinerve*, *A. micranthum*, etc.

***Acer trifidum* HOOK. et ARN. var. *formosanum* HAYATA.** The entire vascular system is virtually the same as in the preceding species, but the component bundles corresponding to v_8 and v_8' in *A. Tschonoskii* (cf. Fig. 7, E) are frequently met with in this species. Further, rarely, a part of the medullary bundles, which in many cases are present at the petiolar top, remain in each nerve as a single or a couple of very minute medullary bundles.

***Acer ukurunduense* TRAUTV. et MEY.** [Fig. 10, C-I]. Leaves 5 to 7-lobed.

The vascular circle in the slender part of the petiole forms in the same way as in *A. parviflorum*, although the components of the ventral bundle corresponding to v_8 , v_4 , v_5 , v_8' , v_4' and v_5' are either very frail, or some or all of them are often absent (cf. Fig. 2, B, C). There are no medullary bundles

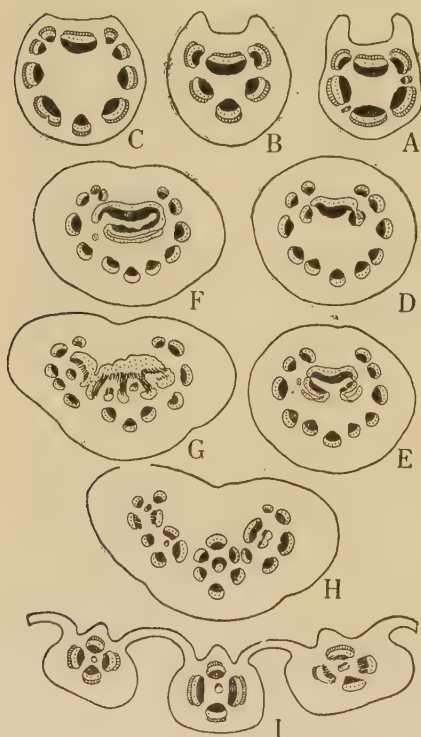


Fig. 10. *A. aizuense* (A, $\times 15$): middle of petiole. *A. trifidum* (B, $\times 15$): middle of petiole. *A. ukurunduense* (C-I, $\times 10$): C, middle of petiole; D-I, petiolar top and lamina base.

throughout the petiole (Fig. 10, C: middle of petiole), while near the petiolar top, both margins of the ventral bundle are folded into the pith, with the result that a large medullary bundle in the form of an arc is formed by the fusion of these folding parts (Fig. 10, D-F).¹⁾ This bundle then divides into a number of parts, some of which become the component of the vascular circle, while others form a medullary bundle in each nerve in the same way as in *A. parviflorum* (Fig. 10, G-I.)



Fig. 11. *A. Oliverianum* var. *Nakaharæ* (A-E, $\times 15$): A-C, higher parts of petiolar base in three different examples; D, middle of petiole; E, petiolar top. *A. pseudo-platanus* (F-J, $\times 10$): F, G, petiolar base; H, middle of petiole; I, petiolar top; J, lamina base.

***Acer Oliverianum* PAX var. *Nakaharæ* HAYATA** [Fig. 11, A-E]. Leaves palmately 5-lobed. In the material used in the present study, cases with three, five

1) Structure of medullary bundle illustrated later (cf. p. 54 and Fig. 25, E).

and intermediate four foliar gaps were found. Although in the case of three foliar gaps, the vascular system in the petiolar base and the slender part is almost the same as in *A. cratægifolium*, the pair of bundles derived from the median trace is small. In Fig. 11, A, which represents a transverse section through a higher part of the petiolar base of a trilacunar example, v_1 , v_1' , v_2 and v_2' are the components of the ventral bundle, the origin of which is indicated by arrows. In the case of four or five gaps, two lateral foliar traces on the same side send out the components of the ventral bundle exactly as in the case of *A. parviflorum* and *A. Tschonoskii* as illustrated in Fig. 11, B, C, both of which show higher positions in the petiolar base in the case of four and five foliar gaps. Here, some of the components of the ventral bundle are occasionally either very small or absent. Absence of such bundles derived from the median trace seems to be very rare in the aceraceous species (Fig. 11, B). In the slender part of the petiole, however, one finds in every case the same conditions (Fig. 11, D: middle of petiole). The medullary bundles and the vascular circles at the petiolar top form in the same way as in *A. micranthum* (Fig. 11, E: detachments of the medullary bundles from their mother bundles are indicated by arrows).

***Acer pseudo-platanus* L.** [Fig. 11, F-J; and Fig. 12, A-I]. Leaves palmately 5-lobed. The vascular system in the base and in the slender part of the petiole strikingly resembles that of *A. parviflorum*. Although the medullary bundle is often formed by the fusion of some bundles that have come from the ventral side as in *A. parviflorum*, it frequently consists only of bundles corresponding to the bundle $a+a'$, or $c+b+a+a'+b'+c'$ in the cited species (Fig. 11, F, G; cf. Fig. 2, C-E). In the slender part of the petiole may be seen a single, rarely three, medullary bundles (Fig. 11, H: middle of petiole). After anastomosing with one another in the higher part of the petiole, they form an arc at the petiolar top among which some small medullary bundles from the vascular circle are interspersed (Fig. 11, I). These complicated behaviours of the medullary bundles may be clearly recognized in our series of figures (Fig. 12, A; for detailed structure cf. p. 49 and Fig. 23, B), which show a single bundle at the petiolar middle of an example and its change as the result of the new addition at the petiolar top (Fig. 12, B-I). In these figures, the xylem and phloem parts derived from the original medullary bundle have been drawn respectively in solid black and a dotted area surrounded by a continuous line, those from the vascular circle respectively in hatched and dotted areas without outline, while in the case of the bundles on the vascular circle, only a part of

which has been drawn as needed, they are shown only in outline. At all events, when the vascular circles for palmate nerves are formed, a part of these medullary bundles goes to form the medullary bundles of nerves, while the other part inserts on the vascular circles of the nerves as in the case of *A. parviflorum* (Fig. 12, I, and Fig. 11, J).



Fig. 12. *A. pseudo-platanus* (A-I, $\times 25$): complicated course of medullary bundles at petiolar top; A, single medullary bundle at middle of petiole; B-I, successive sections of petiolar top. Explanations in text.

Although Col's observations on this species (1904, pp. 137-138 and fig. XXII, 3-8) seem to agree with the present study in so far as they concern the petiolar base and the slender part, he did not describe the complicated course of the medullary bundles or of the new medullary ones at the petiolar top. Moreover, according to his illustration, there seems to be a case in which the medullary bundle is in median nerve alone.

§ 11. *PALMATA*

Acer amœnum CARR. [Fig. 13, A]. Leaves palmately 7-lobed. The whole vascular system markedly resembles that of *A. micranthum*. Issuing forth of the components of the ventral bundle from the lateral traces is comparatively rare, that is, the ventral bundle is usually formed of bundles issued from the median trace alone. In this species are no bundles corresponding to m_1 and m_1' as in the other examples. The vascular circle in the slender part consists of a ventral bundle and a dorsal arc consisting of a median, and four pairs of lateral, bundles (Fig. 13, A: middle of petiole). The medullary bundles formed at the petiolar top are not conspicuous, being very few and minute. These medullary bundles frequently arise in the dorsal bundles and only seldom are those from the ventral bundle added. The vascular circle of each nerve forms quite normally.

Acer ornatum CARR. [Fig. 13, B]. Leaves palmately 7 to 9-lobed. The entire vascular system is virtually identical with that of the preceding species (Fig. 13, B: middle of petiole). At the petiolar base, however, the ventral bundle, as far as has been observed, is always formed of bundles from the median trace alone, while a pair of small bundles, corresponding to m_1 and m_1' in the preceding descriptions, arise from the median bundle on the dorsal arc to join each neighbouring lateral bundle that has originated from the lateral foliar trace. In other respects the vascular system is the same as in the case of *A. amœnum*.

Acer ornatum CARR. var. **Matsumuræ** KOIDZ. [Fig 13, C]. Leaves palmately 7 to 9-lobed. The vascular system is in every respect the same as in that of *A. ornatum* (Fig. 13, C: middle of petiole).

Acer formosum CARR. [Fig. 13, D]. Leaves 7, rarely 5 or 9-lobed. At the petiolar base, the components of the ventral bundle arise from both median and lateral foliar traces, of which those of lateral origin are small. The lateral bundles from the median foliar trace are somewhat large compared with those of other species of this section, and soon fuse with the neighbouring lateral bundles that originate from the lateral trace. All other conditions are the same as in *A. ornatum* except that the medullary bundles at the petiolar top are larger in number and originate mostly from the dorsal bundles (Fig. 13, D: middle of petiole).¹⁾

1) The structure of these medullary bundles is shown in Fig. 25, C.

***Acer Sieboldianum* MIQ.** [Fig. 13, E]. Leaves palmately 9, rarely 7-lobed. At the petiolar base, the components of the ventral bundle of lateral origin are often single, if not altogether absent and, if present, are very small. The dorsal arc consists of a median, and from three to four or rarely five pairs of lateral, bundles. The two ends of the arc incurve and the bundles at the extreme ends are often disposed close to the ventral bundle, while in some extreme cases they are partially fused with their margins (Fig. 13, E). The



Fig. 13. *A. amœrum* (A, $\times 20$): middle of petiole. *A. ornatum* (B, $\times 15$): middle of petiole. *A. ornatum* var. *Matsumurae* (C, $\times 15$): middle of petiole. *A. formosum* (D, $\times 15$): middle of petiole. *A. Sieboldianum* (E, $\times 15$): middle of petiole. *A. Sieboldianum* var. *microphyllum* (F, $\times 15$): middle of petiole. *A. Shirasawanum* (G, H, $\times 15$): G, a higher position of petiolar base; H, middle of petiole. *A. tenuifolium* (I, $\times 15$): middle of petiole. *A. japonicum* (J, $\times 10$): middle of petiole. *A. Heyhachii* (K-N, $\times 10$): K, L, petiolar base; M, middle of petiole; N, petiolar top. In some of these figures the corresponding parts of the outermost margins of the original lateral foliar traces are shown in broken lines.

medullary bundles often form conspicuously at the petiolar top. Most of these arise from the dorsal arc, only a few being derived from the ventral bundle.

***Acer Sieboldianum* MIQ. var. *microphyllum* MAXIM.** [Fig. 13, F]. Leaves palmately 9 or rarely 7-lobed. The whole vascular system is identical with that of *A. Sieboldianum* (Fig. 13, F: middle of petiole).

Acer Shirasawanum KOIDZ. [Fig. 13, G, H]. Leaves palmately 9 to 13-lobed. The ventral bundle forms in the same manner as in *A. Sieboldianum*. The dorsal arc consists in many cases of a median, and from five to six pairs of lateral, bundles at the petiolar base, of which the outermost pair is situated at the incurved ends of the arc (Fig. 13, G: higher part of petiolar base). In the slender part, however, these bundles at the ends are partially fused with the ventral bundle (Fig. 13, H: middle of petiole). Conditions in the petiolar top are also the same as in *A. Sieboldianum*.¹⁾

Acer tenuifolium KOIDZ. [Fig. 13, I]. Leaves palmately 9 to 11-lobed. The whole vascular system of the petiole is the same as in *A. Sieboldianum* (Fig. 13, I: middle of petiole).

Acer japonicum THUNB. [Fig. 13, J]. Leaves palmately 11 to 13-lobed. Frequently the ventral bundle consists of both median and lateral traces, but the components of lateral origin are generally small and in a few cases are altogether absent. The dorsal arc with incurved ends consists mostly of a median and from five to seven pairs of lateral bundles, the bundles on the two extremities often fusing perfectly or partially with the ventral bundle (Fig. 13, J: middle of petiole). Very rarely, a part of m_1 and m_1' , which are branches of the median bundle of the dorsal arc, migrates into the pith to form a single or a small number of medullary bundles which consist chiefly of phloem elements. Also, although very rarely, a small medullary bundle arises from the middle of the ventral bundle at the petiolar base, through which condition the ventral bundle is disposed separately as a pair of bundles through the whole length of the petiole. In every case, numerous medullary bundles are formed at the petiolar top, mostly from the ventral bundle, often also from the dorsal arc. In a few cases, however, in the vascular circle of the median nerve is a single minute medullary bundle.

Acer Heyhachii MATSUM. [Fig. 13, K-N]. Leaves palmately 11 to 13-lobed. Frequently the ventral bundle is mainly formed of components derived from the median foliar trace. As to the manner of formation of the ventral bundle, a single or a couple of pairs of small bundles issue forth into the pith, thus, forming a single, or often a small number of concentric medullary bundles that pass through the whole slender part (Fig. 13, K and L). Excepting the constant occurrence of the medullary bundles in the base and slender part of the petiole, all other features are exactly the same as in *A. japonicum* (Fig. 13, M: mid-

1) The structure of medullary bundles at the petiolar top is shown in Fig. 25, B.

dle of petiole). At the petiolar top, the medullary bundles in the slender part are divided into numerous parts to form, together with those newly issued from the ventral bundle and dorsal arc, an arc formed of numerous minute medullary bundles (Fig. 13, N). A single medullary bundle is sometimes found, though rarely, in the vascular circle of the median nerve or those near the median one.

§ 12. *INTEGRIFOLIA*

***Acer oblongum* WALL.** [Fig. 14, A]. Leaves simple, provided with pinnate nerves. Vascular system in the petiolar base and slender part resembles much that of *A. crataegifolium*. In the slender part the dorsal arc consists of five,

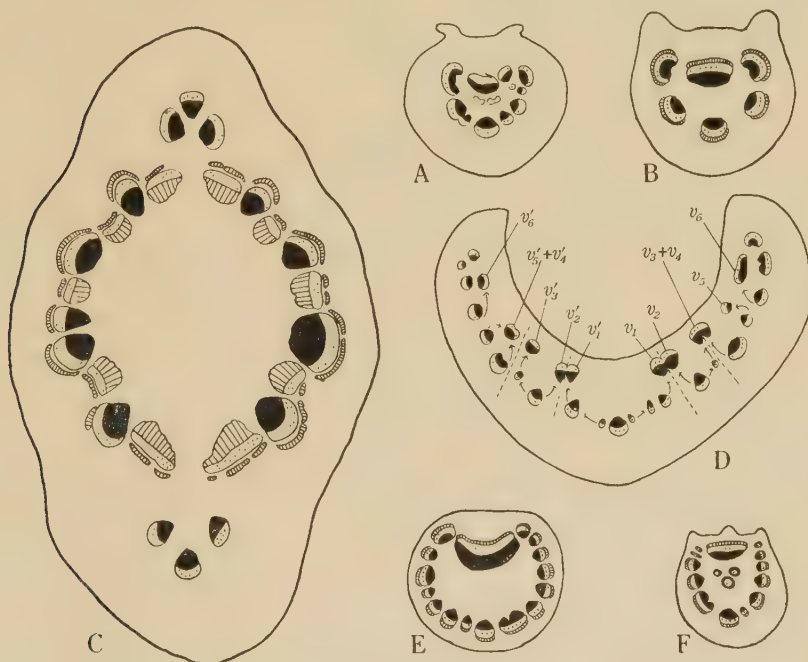


Fig. 14. *A. oblongum* (A, $\times 15$): petiolar top. *A. laevigatum* (B, $\times 15$): middle of petiole. *A. nikoense* (C-F, $\times 10$): C, node of young stem; D, petiolar base; E, middle of petiole; F, middle of petiolule of median leaflet.

rarely of seven or nine bundles. At the petiolar top, both margins of the ventral bundle are incurved and detached to form a few medullary bundles—a situation greatly resembling that in the petiolar top of *A. carpinifolium* (Fig. 14, A). Cases without medullary bundles are met with, though very rarely.

***Acer laevigatum* WALL.** [Fig. 14, B]. Leaves simple. The ventral bundle

is formed chiefly of components from the median trace. The arrangement of bundles of the vascular circle in the slender part is the same as in the preceding (Fig. 14, B: middle of petiole). During my present investigations, no formation of medullary bundles could be observed.

§ 13. *TRIFOLIATA*

Acer nikoense MAXIM. [Fig. 14, C-F]. Leaves palmately compound, provided with three leaflets with short petiolule. So far as the present observation went, five traces arising from distinct gaps go to supply a leaf. In Fig. 14, C, which is a transverse section through a node of certain height, the foliar traces are shown in solid black, of which five on the upper side enter a leaf and the other five on the lower side enter the leaf opposite. The pair of traces near the median one is often fairly small. Soon after entering the petiolar base, the outermost pair of these five traces divide into two, thus forming seven large bundles, or seven groups of bundles through subdivision of every bundle. The components of the ventral bundle arise from every margin of these seven bundles in the same manner as in *A. parviflorum* (Fig. 14, D).¹⁾ In the vascular circle, in the slender part of the petiole, are a large ventral bundle and a dorsal arc consisting of a large number (usually from thirteen to seventeen) of bundles (Fig. 14, E: middle of petiole). Of these dorsal bundles the median and a pair of bundles neighbouring the median have their origin in the median foliar trace.²⁾ These bundles on the vascular circle lie close to one another, and are often almost continuous. At the petiolar top, the vascular circle is divided into three circles, one for each three of the petiolules, each circle consisting of a ventral, and from seven to eleven dorsal, bundles in the same manner as in *A. negundo*. Here the medullary bundles form; a part of them arising from both margins of the ventral bundle in the same manner as that of *A. ukurunduense*, and another part from the dorsal arc. Most of these medullary bundles are inserted into the vascular circle of each petiolule, but some of them retain their medullary position (Fig. 14, F).³⁾

1) In the figure, $v_1, v_1', \dots v_6$ and v_6' are the components of the ventral bundle, their origin being indicated by arrows. The five groups of bundles separate from one another along the broken lines, each group being derived from a single foliar trace.

2) These bundles, which correspond to the m_1 and m_1' of the many examples already given, are seen as a few pairs of small bundles at the petiolar base.

3) Fig. 14, F, shows a transverse section through the median petiolule. There are seen three concentric medullary bundles, the detailed structures of which are shown in Fig. 26.

§ 14. *CAMPESTRIA*

***Acer campestre* L.** [Fig. 15, A, B]. Leaves palmately 5-lobed. The ventral bundle forms in the manner as in *A. cratægifolium*. The dorsal arc usually consists of seven main bundles (Fig. 15, A: middle of petiole). The way in which the medullary bundle arc forms at the petiolar top markedly resembles that in *A. micranthum* (Fig. 15, B: transverse section through petiolar top). A single minute medullary bundle is observed in the vascular circle of the median nerve.

§ 15. *PLATANOIDEA*

***Acer mono* MAXIM.** [Fig. 15, C]. Leaves palmately 5-lobed. Although the composition of the ventral bundle is the same as that in *A. cratægifolium*, it often resembles that of *A. Tschonoskii*. The dorsal arc consists of a median and three (frequently four) pairs of lateral bundles, of which the bundles nearest the median is composed partly of the original median foliar trace and partly of the original lateral traces. The outermost pair of lateral bundles of the dorsal arc are fused with the ventral bundle throughout almost the whole of the slender part, but they revert to the original situation near the petiolar top (Fig. 15, C: middle of petiole). At the petiolar top a few medullary bundles are formed both from the ventral bundle and the dorsal arc, but they are inserted into the vascular circle of each nerve.

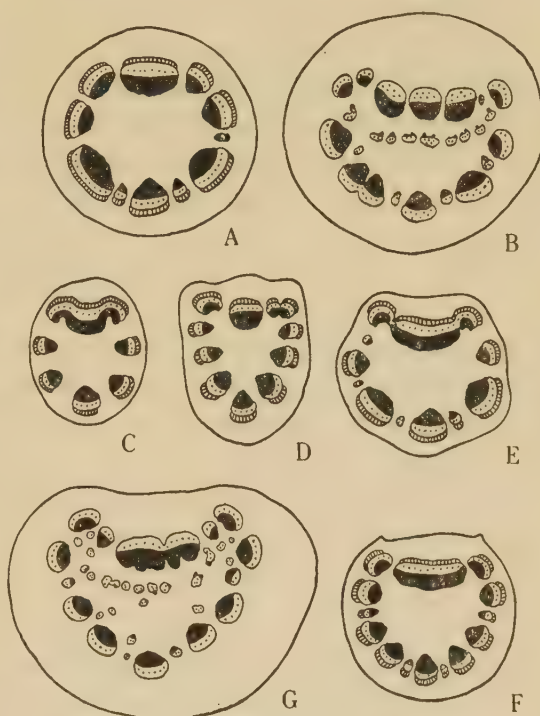


Fig. 15. *A. campestre* (A, B, $\times 15$): A, middle of petiole; B, petiolar top. *A. mono* (C, $\times 8$): middle of petiole. *A. Mayri* (D, $\times 8$): middle of petiole. *A. Miyabei* (E, $\times 8$): middle of petiole. *A. diabolicum* (F, G, $\times 6$): F, middle of petiole; G, petiolar top.

are fused with the ventral bundle throughout almost the whole of the slender part, but they revert to the original situation near the petiolar top (Fig. 15, C: middle of petiole). At the petiolar top a few medullary bundles are formed both from the ventral bundle and the dorsal arc, but they are inserted into the vascular circle of each nerve.

In *Acer mono* MAXIM. var. *Paxii* HONDA, var. *dissectum* HONDA, var.

nikkoense HONDA, var. *velutinum* NAKAI, the same vascular systems are observed.

Acer Mayri G. v. SCHWERIN [Fig. 15, D]. Leaves palmately 5-lobed. As far as my present observation goes, the manner of formation of the ventral bundle is the same as in *A. parviflorum*. The dorsal arc is composed of a median and four (rarely three) pairs of lateral bundles, the outermost pair often being fused in the slender part with the ventral bundle (Fig. 15, D: middle of petiole). In all other respects they are the same as in *A. mono*.

Acer Miyabei MAXIM. [Fig. 15, E]. The type of leaves and conditions of the petiolar base are the same as in *A. Mayri*. In the slender part are a ventral, a median,¹⁾ and three pairs of main lateral bundles; the outermost pair of lateral bundles often becomes continuous with the ventral bundle (Fig. 15, E: middle of petiole); all other conditions being the same as in *A. Mayri*. As an exception, I found a single minute medullary bundle in the vascular circle of the median nerve.

§ 16. *DIABOLICA*

Acer diabolicum BLUME [Fig. 15, F, G]. Leaves palmately 5-lobed. The vascular system in the petiolar base and slender part greatly resembles that of *A. Mayri* (Fig. 15, F: middle of petiole). At the petiolar top, however, numerous medullary bundles are formed from both ventral and dorsal bundles. They are mostly arranged in an arc, but there are also several scattered bundles (Fig. 15, G).²⁾ A single, or rarely a few, minute medullary bundles are formed in the vascular circle of each nerve.

II. Summary of the Vascular System and Remarks on the Structure of Vascular Bundles and on the External Morphological Features of Petioles

I have now described the vascular system in the nodal region, the base, slender part, and top of petiole in each species. From these descriptions and figures it will easily be seen that the vascular system differs with the parts just noticed. As is found to be the usual case in many dicotyledonous species, so also it is found in the aceraceous species that the most complicated construction in the vascular system of the petiole is found in its base and top, for the reason that in the former part, division and fusion of the foliar traces occur in a

1) The structure of the median bundle on the dorsal arc is shown in Fig. 19.

2) The structures of some of these medullary bundles are shown in Fig. 25, D.

characteristic manner, thus determining the characteristic arrangement of the vascular bundles in the main part of the petiole, which, in the petiolar top, is again disturbed by formation of the vascular circles for all the palmate nerves or petiolules, coupled with the fact that the presence of medullary bundles makes the vascular system still more complex. The medullary bundles form at the petiolar base, at the petiolar top, or at both petiolar base and top. The particular manner in which these bundles form and their presence or absence in the basal part of the palmate nerves or the petiolules seem to be important characteristics of the various systematic groups.

The vascular system will now be summarized, while certain outstanding features in connexion with the structure of the bundles and the relationship between the vascular systems and the external morphological features of petioles will also be described.

A. The fundamental vascular system

Regarding the vascular system in the petiole, it will be appropriate to call the system, excluding the medullary one, the "fundamental" vascular system, and in describing and discussing it, the following four parts, namely, (a) the nodal region, (b) the petiolar base, (c) the slender part, and (d) the petiolar top and lamina base, will be considered. In respect to these parts, the following features will be considered: (a) the number of foliar gaps for each leaf, and the number and behaviour of the foliar traces, (b) types of formation of the dorsal arc and the ventral bundle, and the distribution of these types among the systematic groups, (c) topographical arrangement of the petiolar bundles and the correlations between the number of vascular bundles on the dorsal arc and that of the main palmate nerves or leaflets, and (d) the formation of the vascular circle of the palmate nerves or petiolules from the vascular circle in the slender part. Finally a number of interesting features in the histology of the vascular bundles will also be described.

a. The nodal region. On a node of the aceraceous species are two sets of foliar gaps according to the opposite character of the leaves. As pointed out by SINNOT (1914), the number of foliar gaps for a leaf is three in almost every species (e. g., *A. parviflorum*, Fig. 1, A). There are, however, two exceptional species; in *A. nikoense* (Fig. 14, C) the foliar traces for a leaf arise from five distinct gaps, while in *A. Oliverianum* var. *Nakaharæ*, cases of three, five, or an intermediate one of four gaps are observed. At all events a single foliar trace issues from each gap. The median and lateral foliar traces in the case of trilacunar

examples are respectively, sooner or later, divided into three and two. In some species, e. g., *A. parviflorum* (Fig. 1, A, B), such division of the foliar traces occurs almost simultaneously with their departure from the vascular cylinder of the stem, but in most cases the division occurs near the petiolar base. In the case of five foliar gaps, the median and outer pair of lateral traces are divided as in the case of the trilacunar examples, while the lateral traces neighbouring the median one are never divided in this part.

b. Vascular system in the petiolar base. In all aceraceous species, the foliar traces that have issued from the foliar gaps undergo, at the petiolar base, division, fusion, translocation, twisting, etc., the vascular circle thus forming at the slender part of the petiole. This vascular circle can be divided into two parts, namely, the "dorsal arc" situated on the dorsal side of the petiole and consisting of a certain number of separated bundles that are usually alike in size, and a large "ventral bundle" on the ventral side. The manner in which these form will be described as we proceed.

1. Formation of the dorsal arc. Frequently, the median foliar trace undergoes division to form three bundles almost simultaneously with their departure from the vascular circle of the stem. The laterals of these bundles are almost always again divided, each into two parts, which may or may not be almost equal in their sizes, thus forming five bundles. In the foregoing figures and descriptions, the bundles in these extremities are designated v_1 and v_1' , the median one m , and the other two situated between v_1 and m , and v_1' and m , by m_1 and m_1' . Of these, m , m_1 and m_1' are components of the dorsal arc, and v_1 and v_1' those of the ventral bundle. In some species, the sizes of these five bundles derived from the median foliar trace are either almost alike, or m_1 and m_1' are slightly smaller than the others. This condition is found in the species § *Parviflora* (Fig. 2, B: *A. parviflorum*) and § *Indivisa* (e. g., Fig. 3, B: *A. distylum*) among subgn. *Intrastaminalia* and species of § *Negundo*, § *Cissifolia*, § *Rubra* (Fig. 9, D: only in *A. dasycarpum*), § *Spicata* (except *A. Oliverianum* var. *Nakaharæ*), § *Integrifolia* (*A. oblongum* only), § *Trifoliata* (Fig. 14, D: *A. nikoense*), § *Campestris*, § *Platanoidea* and § *Diabolica* among subgn. *Extrastaminalia*. In some of the other species, on the other hand, bundles m_1 and m_1' are very much smaller than v_1 and v_1' , or are, rarely, altogether absent; examples being the species of § *Carpinifolia* (Fig. 5, A: *A. carpinifolium*), § *Macrantha* (e. g., Fig. 6, B: *A. rufinerve*), § *Palmatoidea* (e. g., Fig. 7, B: *A. micranthum*) and § *Arguta* among subgn. *Intrastaminalia* and species of § *Rubra* (only in *A. pycnatum* var. *rubrum*), § *Spicata* (*A. Oliverianum* var. *Nakaharæ*

only; Fig. 11, A-C), § *Palmata* (e. g., Fig. 13, K: *A. Heyhachii*) and § *Integri-folia* (only in *A. lævigatum*) among subgn. *Extrastaminalia*. Sometimes in *A. micranthum* and *A. argutum*, and always in *A. lævigatum*, bundles m_1 and m_1' are altogether absent. Thus it may be said that of these two conditions, the former is mainly observed in subgn. *Extrastaminalia*, while the latter is widely prevalent in subgn. *Intrastaminalia* and in a few limited sections¹⁾ of subgn. *Extrastaminalia*. On the other hand, all the components of the lateral bundles of the dorsal arc, excepting m_1 and m_1' , are derived from the lateral foliar traces. To a certain extent the number of bundles on the dorsal arc seems to be related in some way with the number of nerves or leaflets as will be referred to more fully later.

The bundles m_1 and m_1' that connect the median and lateral foliar traces in the dorsal arc are usually fused with the innermost lateral bundles of lateral trace origin, the fusion being, however, often unstable. When bundles m_1 and m_1' are very frail, the connection of the median and lateral foliar traces is shown only by these weak bundles, while in cases without these bundles m_1 and m_1' , it is obvious that there are no connections. At all events, we may conclude that there are no important connections between the median and lateral foliar traces, while the vascular system in the petiolar base in the aceraceous species differs altogether from that in the leguminous species treated in my previous paper (1934).

On the other hand, both absence or presence of m_1 and m_1' and their sizes seem to be closely related to the manner in which the ventral bundle is formed, which subject will be referred to again later.

2. *Types of formation of the ventral bundle.* The ventral bundle forms at the petiolar base simultaneously with that of the dorsal arc. The manner in which it forms may roughly be said to consist of three different types. In the first type the components of the ventral bundle are derived from the margins of the original median foliar trace alone (Fig. 16, B). These bundles v_1 and v_1' approach each other by gradual incurving and translocation towards the ventral direction of the petiole, until they fuse into a ventral bundle. Consequently, the orientation of the ventral bundle thus formed is inverse relatively to the position of the phloem and xylem. This type of ventral bundle formation is marked *M* in column "VB," Table III, and is usually observed in the

1) Nearly all the representatives of this type belong to § *Palmata*; only a single example having been observed in each of the other sections.

species of \S *Macrantha* (e. g., *A. rufinerve*, Fig. 6, A-C) and \S *Palmatoidea*, in subgn. *Intrastaminalia*; and of \S *Palmata* (always or generally always, in *A. amcenum*, *A. ornatum* and *A. ornatum* var. *Matsumuræ*) among subgn. *Extrastaminalia*.¹⁾ Consequently, the distribution of this type is very limited, i. e., it is found only in two allied sections of the first subgenus and one section of the second subgenus.

As the second type, we shall select the case in which the components of the ventral bundle are chiefly derived from the median foliar trace, only a small part originating from the lateral foliar traces. This type can be subdivided into two cases; the first which is designated by *M(L)-a* in Tab. III, the ventral bundle consisting of a pair of large components v_1 and v_1' derived

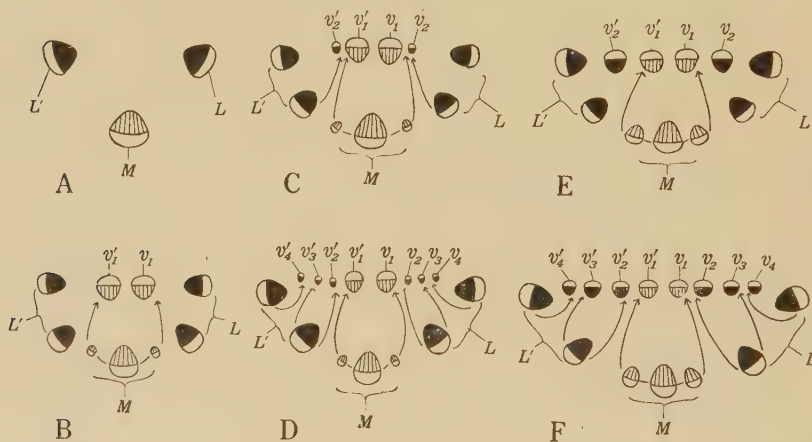


Fig. 16. Diagrammatical figures showing types of formation of ventral bundle at petiolar base. Xylem of bundles derived from the median foliar trace is indicated by the shading and that from the lateral traces by solid black. Explanation in text.

from the median foliar trace, and a pair of minute bundles v_2 and v_2' , derived from the innermost margins of each of the lateral foliar traces (Fig. 16, C). Bundles v_2 and v_2' are situated on each extremity of the ventral bundle. Frequently, however, either v_2 or v_2' is wanting. In subgn. *Intrastaminalia*, this condition is, though rarely, found in *A. rufinerve* and *A. micranthum* (Fig. 7, A-C), while in subgn. *Extrastaminalia*, it is found always or generally always

1) Among species of these sections, *A. rufinerve* (\S *Macrantha*), *A. micranthum* (\S *Palmatoidea*), and *A. amcenum* (\S *Palmata*) rarely show the second type, while *A. Tschonoskii* (\S *Palmatoidea*) rarely shows the first mentioned type. Besides the species of \S *Palmata* just mentioned, five other species rarely show this type.

in many species of § *Palmata*.¹⁾ *A. lævigatum* (§ *Integrifolia*) also shows this condition. In the second case of this type which is shown in Tab. III under the sign *M(L)-b*, the ventral bundle is formed by the fusion of a pair of fairly large components v_1 and v_1' of median trace origin and several minute ones v_2 , v_2' , v_3 , v_3' , v_4 , v_4' , etc., all of which arise from all or several margins of the divided (mostly into from two to three) lateral foliar traces (Fig. 16, D). This is only found in *A. Tschonoskii* (§ *Palmatoidea*) (Fig. 7, E-G) and, rarely, in *A. Shirasawanum* (§ *Palmata*).

The third type is characterized by the ventral bundle being a fusion of components of nearly the same size as that derived from the median as well as the lateral foliar traces. This type may also be divided into two cases in the same sense as in that of the second type. In the first case, the ventral bundle is composed of four components, v_1 , v_1' , v_2 and v_2' , of sizes almost alike, while the departures of these bundles occur from the original median and lateral foliar traces in the same manner as in the first case of the second type (Fig. 16, E). This case, indicated by the sign *ML-a* in Tab. III, is widely distributed among the aceraceous species. In subgn. *Intrastaminalia*, this condition is seen in species of § *Indivisa* (Fig. 3, A-E: *A. distylum*; Fig. 4, A: *A. cratægifolium*), § *Carpinifolia* (*A. carpinifolium*,²⁾ Fig. 5, A-C), § *Arguta*, and in subgn. *Extrastaminalia*, in all species of § *Cissifolia*, § *Rubra* (Fig. 9, D-F: *A. dasycarpum*)³⁾ § *Campestris*, and in some of § *Spicata*,⁴⁾ *A. oblongum* (§ *Integrifolia*), *A. mono* and its varieties (§ *Platanoidea*) and rarely in *A. japonicum* (§ *Palmata*). The ventral bundle in the second case is formed by the fusion of components v_1 , v_1' , v_2 , v_2' , v_3 , v_3' , etc., which, in their origin from the original median and lateral foliar traces, exactly correspond to the second type. The components derived from the divided lateral foliar traces are, however, usually fairly large, bundles v_2 and v_2' having at least almost the same size as that of v_1 and v_1' . Sometimes a few of these components are either minute or altogether absent. This is found only in *A. parviflorum* (Fig. 2, A-

1) Namely, *A. formosum*, *A. Sieboldianum*, *A. Sieboldianum* var. *microphyllum*, *A. Shirasawanum*, *A. tenuifolium*, *A. japonicum* and *A. Heyhachii*, and also, though rarely, in *A. amœnum*.

2) In this species, v_1 , v_2 and v_1' , v_2' are each fused to form a pair of ventral bundles that are never fused in the slender part, their fusion occurring after they enter the midrib of the lamina (cf. pp. 11-12).

3) In *A. pycnatum* var. *rubrum*, cases of *M(L)-a* are rarely observed.

4) Namely, always in *A. aizuense*, *A. trifidum*; and sometimes in *A. trifidum* var. *formosanum* and *A. Oliverianum* var. *Nakaharæ* (Fig. 11, A).

E) (§ *Parviflora*) in subgn. *Intrastaminalia*, and, in subgn. *Extrastaminalia*, in § *Negundo* (*A. negundo*: Fig. 8, A-H), § *Spicata* (nearly always in *A. ukurunduense*; always in *A. pseudo-platanus*, Fig. 11, F and G; and sometimes in *A. trifidum* var. *formosanum*, and *A. Oliverianum* var. *Nakaharæ*, Fig. 11, C), § *Trifoliata*, § *Platanoidea* (in *A. Mayri* and *A. Miyabei*) and § *Diabolica*. The formation of the ventral bundle from the pentalacunar traces in *A. nikoense* (Fig. 14, C and D) and the same case in *A. Oliverianum* var. *Nakaharæ* may be placed in this category.

Although the distribution of the types above-mentioned could be known from Tab. III and from the foregoing description, I append here for convenience of understanding a table (Tab. I) showing the distribution of these types among

Tab. I. Distribution of types of ventral bundle formation
at the petiolar base.

The number of species in figures. A. subgn. *Intrastaminalia*,
B. subgn. *Extrastaminalia*.

Sections	M	M(L)	ML	Sections	M	M(L)	ML
A				9. <i>Rubra</i>			2
1. <i>Parviflora</i>			1	10. <i>Spicata</i>			6
2. <i>Indivisa</i>			2	11. <i>Palmata</i>	2	8	
3. <i>Carpinifolia</i>			1	12. <i>Integrifolia</i>		1	1
4. <i>Macrantha</i>	3			13. <i>Trifoliata</i>			1
5. <i>Palmatoidea</i>	1	1		14. <i>Campestris</i>			1
6. <i>Arguta</i>		1		15. <i>Platanoidea</i>			7
B				16. <i>Diabolica</i>			1
7. <i>Negundo</i>			1				
8. <i>Cissifolia</i>			1	Total	6	11	25

the 16 sections. As will be seen from this table, the first type *M*, the second type *M(L)* and the third type *ML* are respectively represented by 6, 11, and 25 species. The first type is limited to species in three sections, namely § *Macrantha* (3 species), § *Palmatoidea* (1 species), and § *Palmata* (2 species), the second to those of sections that are either the same as or are intimately allied to representatives of the first, namely, § *Palmatoidea* (1 species), § *Arguta* (1 species), § *Palmata* (8 species), § *Integrifolia* (1 species). The third type shows, however,

that it prevails in the sections or species already represented in the first and second types, namely, species of three sections § *Parviflora*, § *Indivisa*, and § *Carpinifolia* in subgn. *Intrastaminalia*, and all the species except those belonging to § *Palmata*,¹⁾ and one of § *Integrifolia* (*A. lævigatum*) in subgn. *Extrastaminalia*.

Lastly, the second cases of the second and the third types, i.e., *M(L)-b* and *ML-b*, which are characterized by a fairly large number of components, consist mostly of species provided with somewhat vigorous leaves, such as *A. parviflorum*, *A. negundo*, *A. pseudo-platanus*, *A. nikoense*, etc., so that it is probable that this condition is to a certain extent intimately related to the size of the leaves.

These types of ventral bundle formation moreover seem to be closely correlated with the presence, absence, or size of the bundles m_1 and m_1' , referred to in the preceding article. That is, in representatives of the third type, these bundles are most always large,²⁾ whereas in those of the first and second types they are minute or, rarely, altogether absent.³⁾ These correlations may easily be recognized upon comparing column " m_1 " in Tab. III with "VB."

c. Arrangement of vascular bundles in the slender part, and the correlation between the number of vascular bundles on the dorsal arc and the number of palmate nerves or leaflets. In the preceding article it was shown that the manner of formation of the vascular system consisting of a dorsal arc of a certain number of bundles as also that of a large ventral bundle could be divided into several different types. The arrangement of the vascular bundles on the circle, however, shows only a few slightly differing conditions, so that from these aspects alone, one would scarcely imagine that these arrangements of vascular bundles in the slender part were derived from conditions so different in the petiolar base. We shall now consider the arrangement of the vascular bundles and the correlation between their number on the dorsal arc and the number of palmate nerves or leaflets. For the arrangement of vascular bundles in the slender part, we shall select for convenience, the condition in a transverse section through approximately the middle of the whole length of the petiole, for the reason that in the slender part, except a small portion near

1) *A. japonicum*, however, although rarely, shows the third type.

2) *A. carpinifolium*, *A. pycnatum* var. *rubrum*, and *A. Oliverianum* var. *Nakaharæ* are the exceptions.

3) Absence of these bundles is noticed in *A. micranthum*, *A. argutum*, *A. amoenum*, and *A. lævigatum*.

the petiolar base or top, the topographical arrangement of the vascular bundles shows almost the same features.

The relative position between the dorsal arc and the ventral bundle seems to show, in many cases, a certain correlation with the outline of the transverse section of the petiole. That is to say, where it has a round outline, the petiolar bundles are arranged on the periphery in a circle (e.g., *A. cissifolium*, Fig. 9, A; *A. pycnatum* var. *rubrum*, Fig. 9, C; etc.), but when the ventral part is more or less flattened, the ventral bundle generally forms the chord of the dorsal arc, or is slightly inside the chord (e.g., *A. diabolicum*, Fig. 15, F; *A. ukurunduense*, Fig. 10, C). However, when the ridges and groove are prominent, the ventral bundle is usually situated within the concavity of the dorsal arc (e.g., *A. rufinerve*, Fig. 6, D; *A. micranthum*, Fig. 7, C; *A. Shirasawanum*, Fig. 13, H; etc.),¹⁾ while in the last case, the ends of the dorsal arc are often folded inwards (e.g., *A. ornatum*, Fig. 13, B; *A. Sieboldianum* var. *microphyllum*, Fig. 13, F; etc.). But we meet with some exceptions, in which the petiolar outline is round, notwithstanding that the ventral bundle lies at a certain depth in the concavity of the arc (e.g., *A. mono*, Fig. 15, C; etc.), or it may even happen that the ventral groove is poor, the ventral bundle sinking deeply into the concavity of the dorsal arc (e.g., *A. japonicum*, Fig. 13, J; *A. Heyhachii*, Fig. 13, M; etc.).

In certain species, the bundles on both extremities of the dorsal arc are fused to a marked degree with the ends of the ventral bundle (e.g., *A. parviflorum*, Fig. 2, F; *A. negundo*, Fig. 8, I; *A. mono*, Fig. 15, C; etc.). In such a case, it is sometimes difficult to distinguish the arc ends and the ventral bundle, so that its nature may be known only from the condition of the petiolar base.

As already said (cf. pp. 32-33), there are three components of the dorsal arc having their origin in the median foliar trace, and which are designated *m*, *m*₁ and *m*₁', the last two of which are often very frail or altogether absent, and are, usually fused, sooner or later, completely or partially with the neighbouring bundle that originated from the lateral foliar trace; while on the other hand each lateral foliar trace supplies at least two bundles by dividing, so that the minimum number of bundles on the dorsal arc in the slender part is five (e.g., *A. cratægifolium*, Fig. 4, B; *A. pycnatum* var. *rubrum*, Fig. 9, C; *A. aizuiense*, Fig. 10, A; etc.). When the dorsal bundles are seven, it is usually

1) As will be mentioned later (cf. p. 59 sqq.), there are primary and secondary ridges, but the arrangement of the vascular bundles seems to be independent of these features.

through division of the bundles at the ends (e.g., *A. micranthum*, Fig. 7, C; *A. rufinerve*, Fig. 6, D; *A. argutum*, Fig. 7, H; etc.). Further multiplication of bundles also occurs as the result of division of those of lateral origin (e.g., *A. japonicum*, Fig. 13, J; *A. nikoense*, Fig. 14, E; *A. diabolicum*, Fig. 15, F; etc.).

We shall next consider the relation between the number of dorsal bundles and that of palmate nerves or leaflets, these numbers in each species being shown by numerals in Tab. III in columns "d" and "n." The number of nerves or leaflets is frequently an important feature in taxonomy. In species having simple leaves with pinnate nerves, such as *A. oblongum* and *A. lævigatum*, the number of main petiolar bundles is almost always five, representing the minimum number in this genus as just mentioned. But *A. carpinifolium* is an exception in having nine. When the number of nerves or leaflets is three ($n=3$), that of the dorsal bundles is mostly five ($da=5$) (*A. cratægifolium*, *A. cissifolium*, *A. pycnatum* var. *rubrum*, *A. aizuiense*, *A. trifidum*, *A. trifidum* var. *formosanum*) or seven ($d=7$) (*A. negundo*), whereas in *A. nikoense*, the number is exceptionally large ($da=13-17$). In the case of five nerves, they have seven dorsal bundles (§ *Macrantha*, § *Palmatoidea*, *A. distylum*, *A. campestris* and *A. Miyabei*), or from seven to nine (*A. parviflorum*, *A. negundo*, *A. dasy-carpum*, *A. Oliverianum* var. *Nakaharæ*, *A. mono* and its varieties, and *A. Mayri*), and, rarely, nine (*A. diabolicum*), or from seven to eleven (*A. pseudo-platanus*). In *A. ukurunduense*, the nerves number from five to seven and the arc bundles are correspondingly from seven to nine; in species of § *Palmata*, the number of palmate nerves often exceed seven and the number of bundles on the dorsal arc are correspondingly large, namely, *A. formosum* ($n=5-7(9)$, $da=7-9$), *A. amœnum* ($n=7$, $da=9$), *A. ornatum* ($n=7-9$, $da=9-11$), *A. ornatum* var. *Matsumuræ* ($n=7-9$, $da=9$), *A. Sieboldianum* ($n=9(7)$, $da=7-11$), *A. Sieboldianum* var. *microphyllum* ($n=9(7)$, $da=9-11$), *A. tenuifolium* ($n=9-11$, $da=7-9$), *A. Shirasawanum* ($n=9-13$, $da=11-13$), *A. japonicum* ($n=11-13$, $da=11-15$) and *A. Heyhachii* ($n=11-13$, $da=11-15$).

It is thus easy to see that the number of dorsal bundles is usually one or two pairs more than that of the nerves or leaflets, and that cases in which the number of dorsal bundles greatly exceeds, is equal to, or less than that of the nerves or leaflets, are comparatively very rare, whence it would be in order to conclude that there is parallel correlation to a high degree between the number of bundles arranged on the dorsal arc and that of the nerves or leaflets.

d. Vascular system in the petiolar top. Although the fundamental vascular

system in the petiolar base shows a variety of conditions as just described, that in the petiolar top may be attributed to a single type if the differences in the number of the vascular circles of nerves or of petiolules formed are ignored. As an example of the fundamental vascular system in the petiolar top, two diagrammatic figures are appended, the example selected being the five palmate nerves (Fig. 17). Fig. A is a transverse section through a certain height of the petiolar top or the extreme base of the lamina, in which may be seen five vascular circles for five nerves (n_0, n_1, n_1', n_2 and n_2'), each of which consists of six vascular bundles. It is shown in the figure that the xylems indicated by the shaded parts have their origin in the dorsal bundles in the slender part, and those in solid black in the ventral; that is to say, in each vascular circle of n_0, n_1, n_1' , three bundles on the dorsal half (e.g., 1, 2, 2' in n_0) are of dorsal origin while the ventral three (e.g., a, b, b' in n_0), are

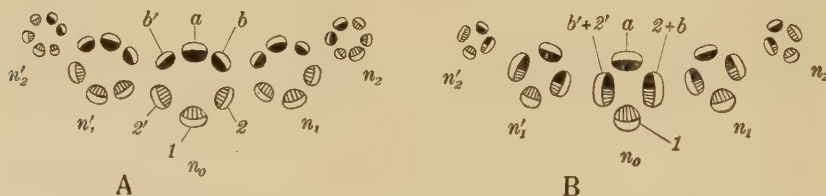


Fig. 17. Diagrammatic figures showing the constitution of the vascular circles of nerves (n_0, n_1 , etc.). Xylem derived from ventral bundle is indicated in solid black, and that from dorsal arc shaded. Explanations in text.

of ventral origin; but in the outermost circles (n_2 and n_2') the constitution slightly differs from the former three in that a bundle at the extreme corner comes from the end of the dorsal arc. As a rule, though the number of nerves varies with species, a pair of vascular circles at the extreme ends shows the constitution of the latter and the intermediate ones the constitution of the former. This situation of the vascular circles in each nerve, however, soon assumes the condition shown in fig. B: that is, two lateral bundles of each circle (2 and $b, 2'$ and b' in n_0) respectively fuse to form a circle of four bundles, a dorsal, a ventral (a), and a pair of lateral ones ($2+b$ and $2'+b'$).¹⁾ These four

1) When there are medullary bundles, they insert, in many cases, between bundles 2 and b , and $2'$ and b' of the median nerve or the corresponding parts of other nerves (e.g., *A. parviflorum*, cf. p. 8 and Fig. 2, L), but rarely, also between a and b , and a' and b' (e.g., *A. rubescens*, cf. p. 14; *A. argutum*). Also in some species, they fuse with the ventral bundle in a certain vascular circle into a ringlet (e.g., *A. parviflorum*, Fig. 2, M; *A. distylum*, Fig. 3, I).

bundles further fuse into a ventral bundle and a dorsal arc (a and $b+2+1+2'+b'$ in n_0). The vascular circle in the petiolules of *A. negundo*, however, consists of a ventral, which often forms a ringlet by fusion with the medullary bundles, from seven to nine bundles being arranged in an arc (Fig. 8, O, Q). In *A. nikoense*, from seven to eleven bundles are arranged on the dorsal arc of a petiolule (Fig. 14, F). These bundles at the lateral sides are smaller than in the median parts; their lateral three to four pairs corresponding to a pair of lateral bundles in a normal case.

In considering the origin of the dorsal half of these vascular circles for the nerves or petiolules from the original foliar traces, I shall begin by describing the bundles m_1 and m_1' at the petiolar base (cf. pp. 32–33). When the bundles m_1 and m_1' are large and the number of palmate nerves are five or more, three dorsal bundles on the vascular circle of the median nerve ($1, 2, 2'$ in Fig. 17, A) come entirely from the original median foliar trace, and those on the vascular circles of other nerves from the original lateral foliar traces. The following species belong in this category: *A. parviflorum* (Fig. 2, G–M), *A. distylum* (Fig. 3, F–I), *A. dasycarpum*, *A. trifidum*, *A. ukurunduense* (Fig. 10, D–I), *A. pseudo-platanus*, *A. campestre*, all species of § *Platanoidea* and *A. diabolicum*. When the number of palmate nerves or leaflets is three, both laterals of dorsal bundles in the median circle usually consist of components from both median and lateral foliar traces, and those on the other circles from the lateral traces alone, of which *A. crataegifolium* (Fig. 4, *A. cissifolium*, *A. aizuense* and *A. nikoense* are examples. Next, for the case when the two bundles m_1 and m_1' are minute or altogether absent, both laterals of dorsal bundles in the median circle consist, independently of the number of nerves or leaflets, of both median and lateral traces; and those on the other circles of lateral traces alone. All species of § *Macrantha* (e. g., *A. rufinerve*, Fig. 6, E–H), of § *Palmatoidea*, of § *Palmata*, *A. argutum*, *A. pycnatum* var. *rubrum* and *A. Oliverianum* var. *Nakaharæ* belong in this category. In such examples as are provided with no palmate nerves or leaflets, but with pinnately nerved simple leaves (e. g., *A. carpiniifolium*, *A. oblongum*, *A. lævigatum*), both laterals of the midrib consist as a natural consequence of components from both median and lateral traces. In *A. negundo*, a rare thing in this family, the leaves, which are pinnately compound, are provided with three or five leaflets and a vascular circle in each petiolule, consisting, as already mentioned, of a ventral bundle and of from seven to nine bundles arranged in an arc. In this case, the one or two pairs neighbouring the median correspond to the

said bundles, being only of lateral trace origin in the lateral leaflets and only of median trace origin in the terminal leaflet. In short, of the dorsal arc, the part that has formed from the original median foliar trace is distributed only in the median palmate nerves or leaflets; and, in some species, the parts from the original lateral traces in both median and lateral nerves or leaflets and in others only in the lateral nerves or leaflets.

Next, we shall consider the relations between the composition of the ventral bundle in the slender part and that of the vascular circle of nerves or leaflets in the petiolar top. That the three bundles on the ventral side of the vascular circle in each of the palmate nerves or leaflets are derived from the ventral bundle in the slender part was already mentioned in the beginning of this article, while it was also mentioned in a foregoing article (pp. 33-37) that the types of ventral bundle formation at the petiolar base could be placed in three types (*ML*-, *M(L)*- and *M*-types), as a natural consequence of which the latter characters are intimately related to the former when one considers that the composition of these bundles is due entirely to the original foliar traces.¹⁾ That is, in the *ML*-type, in which the ventral bundle is derived from both median and lateral foliar traces in nearly equal proportion, the three bundles on the ventral side of the median (e. g., bundles *a*, *b*, *b'* in Fig. 17, A) and a few neighbouring vascular circles come entirely from the original median foliar trace, and those of a few lateral nerves from the original lateral trace when one assumes a case with a number of palmate nerves. In the *M*-type, the ventral bundle is derived from the median trace, so that these three ventral bundles in all the nerves come entirely from the original median foliar trace, whereas the *M(L)*-type is an intermediate condition between the first two.

Upon comparing the vascular system in the petiolar top in the aceraceous species with that in the palmately compound or nerved leaves in the leguminous species, which were treated by the writer (1934), both groups show considerable agreement, the only difference seems to be that whereas, in the leguminous species the vascular bundles in the nerves or petiolules are fused into a more or less deeply curved arc, both extremities of which consist of the original ventral bundle or bundles corresponding to it, in the aceraceous species there is also found a small ventral bundle in each vascular circle of nerves or petiolules.

e.. The structure of vascular bundles in the fundamental vascular system. As

1) In some cases, however, these relations seem to be disturbed to a certain extent by the formation of a large medullary bundle at the petiolar base.

is the case with many dicotyledonous petioles, the collateral structure of bundles of the fundamental vascular system also usually obtains in *Acer*. There are, however, a few interesting points in the arrangement of the elements of the phloem that seem to offer some important suggestions regarding the affinities among the aceraceous species. We also find, though only in a few species, some other noteworthy types of structure of bundles, the amphicribal concentric or subcollateral bundles, for example. The structure of these bundles will be referred to later.

1. *The petiolar bundles with normal collateral structure.* The vascular bundles on the dorsal arc almost always show a collateral structure. Although there are no peculiarities in the xylem part, since the woody elements consist of several rows of vessels, cambium activity usually adds some vessels and fibrous elements. These characters widely prevail in all species. The phloem part, however, presents certain characteristic features. In the species studied so far, sieve-tubes and companion cells are usually crowded together to form groups, which, hereafter will be referred to merely as "sieve-tube groups." The arrangement of these sieve-tube groups and parenchymatous and secretory¹⁾ elements in the phloem seems to call for some attention as will be shown later.

The relative position between the sieve-tube groups and parenchymatous and secretory elements can roughly be divided into the following three conditions: (1) a few somewhat large groups of sieve-tubes are disposed more or less separated from one another by marked parenchymatous and secretory elements; (2) in contrast to (1) the sieve-tube groups are arranged in a continuous layer, although interrupted radially by some comparatively small medullary rays, the parenchymatous and secretory elements chiefly appearing in that part which is at a distance from the cambium; (3) this is a condition intermediate between (1) and (2), sieve-tube groups of either uniform or different sizes mingling somewhat irregularly with the parenchymatous and secretory elements. Conditions (1), (2), (3), however, frequently represent the characteristic features of each species, although some of the species may represent (1) or (2) or conditions intermediate between the two. Some examples of these three conditions now follow.

1) The secretory elements are frequently strikingly large. WARSOW (1903), who studied from the view point of systematic anatomy had studied the leaves of about a hundred aceraceous species, including many species treated in the present study, always observed more or less large elements containing either a typical "Milchsaft" in some species (i. e., in all species of § *Platanoidea* and in some of § *Lithocarpa*) or a substance that is closely allied to the "Milchsaft," or some other substance, in others.

(1) A typical example of the first type is *A. rufinerve*. Fig. 18 shows the median petiolar bundle. The xylem consists of about ten rows of chains of vessels, in each of which several vessels are seen. Surrounding the xylem in the form of an arc are seen five fairly large groups of sieve-tubes, each of which are separated by from two to three radial rows of large parenchymatous and secretory elements. Other examples of this type are *A. distylum* and *A. argutum*, while *A. parviflorum*, *A. crataegifolium*, *A. Tschonoskii*, *A. cissifolium*, *A. pycnatum* var. *rubrum* and *A. ukurunduense* seem also to belong in this category, although some of them often show features of the third type.

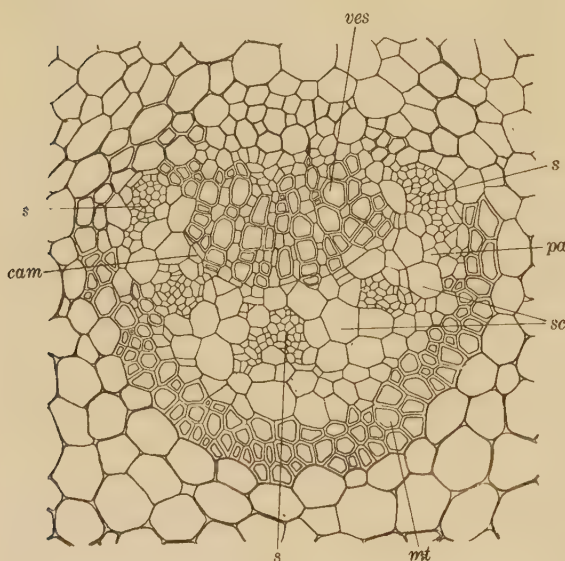


Fig. 18. A median bundle in slender part of petiole in *A. rufinerve* (ca. $\times 180$). *ves*, vessel; *s*, sieve-tube group; *sc*, secretory element; *pa*, parenchyma; *cam* cambium; *mt*, mechanical tissue.

elements forming a zone outside the phloem. *A. campestre* is an excellent example of this type. Further, *A. aizuense*, *A. pseudo-platanus*, species of \S *Palmata*, \S *Integrifolia*, \S *Trifoliata*, \S *Platanoidea* and \S *Diabolica* should belong to this type. Of these, *A. aizuense* (\S *Spicata*), *A. Sieboldianum* (\S *Palmata*), *A. amoenum* (\S *Palmata*), and *A. oblongum* (\S *Integrifolia*) often show an intermediate condition (3).

(3) The third or intermediate type of the former two is typically represented by *A. carpinifolium*, *A. negundo* and *A. dasycarpum*. In these species the

(2) As a good example of the second type, the median petiolar bundle in *A. Miyabei* is shown in Fig. 19. One may see at a glance certain marked differences when compared with that of *A. rufinerve* in the arrangement of the sieve-tube groups and in the large elements, whereas in the woody part the arrangement of the vessels are almost alike. The sieve-tube groups are arranged in a zone, which however is interrupted only by a few radial rows of ray tissue, the parenchymatous and secretory

arrangement of xylem elements is the same as in the former two examples. In the phloem, however, somewhat small sieve-tube groups and the secretory and parenchymatous elements mingle with one another almost in uniform distribution. The size of a sieve-tube group is almost the same as that of a parenchymatous or secretory element.

An examination into the distribution of these types among the aceraceous species as systematically arranged reveals the interesting and noteworthy fact that most species in the sections of subgn. *Intrastaminalia* are characterized by type (1), except *A. carpinifolium*, which is characterized by type (3), while type (2) is confined to species in subgn. *Extrastaminalia*, except *A. ukurunduense* and *A. pycnatum* var. *rubrum* by type (1), and *A. dasycarpum*, *A. negundo* and rarely *A. aizuense* together with a few species in \S *Palmata*, *A. oblongum* are characterized by type (3).

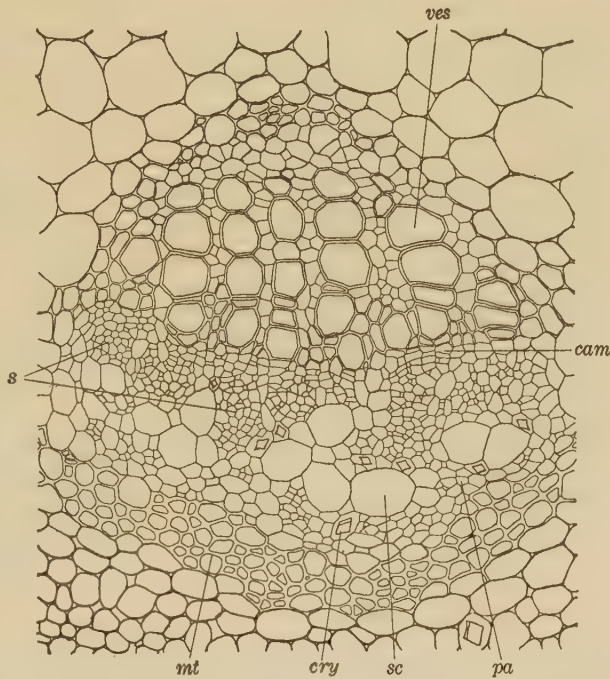


Fig. 19. A median bundle in slender part of petiole in *A. Miyabei* (ca. $\times 180$). *cry*, crystal; other abbreviations as in Fig. 18.

Frequently the vascular bundles forming the dorsal arc are almost all of the same size, although a few smaller ones are often inserted between them. Its structure is also collateral, but, as a rule, the development of the xylem part is smaller than that of the phloem part.

2. *Concentric and sub-collateral structure of the vascular bundles.* Among the petiolar bundles on the fundamental vascular system are found, rarely,

those of amphicribal concentric, of crescentic, or of sub-collateral¹⁾ structure. Such forms of structure are frequently found in a single or a couple of bundles situated on the arc ends in *A. rufinerve* (Fig. 6, D) and *A. capillipes* (Fig. 6, I). The concentric structure of a bundle in *A. rufinerve* is shown in Fig. 20. The rows of vessels are radially developed to form a closed xylem ring which is surrounded by a phloem ring consisting of several sieve-tube groups and parenchymatous and secretory elements. Often the bundle at the arc end in *A. cratægifolium* and *A. pseudo-platanus* also shows this structure. The bundle in *A. rufinerve* too frequently shows a crescentic structure instead of complete concentric ones (Fig. 21). Such a case is also found in *A. cratægifolium* and in many species of \S *Platanoidea*. Moreover, there is found sometimes a

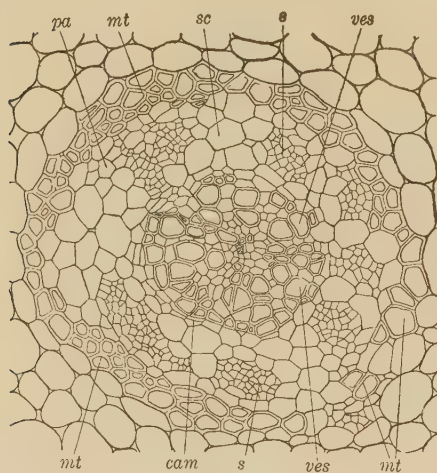


Fig. 20.

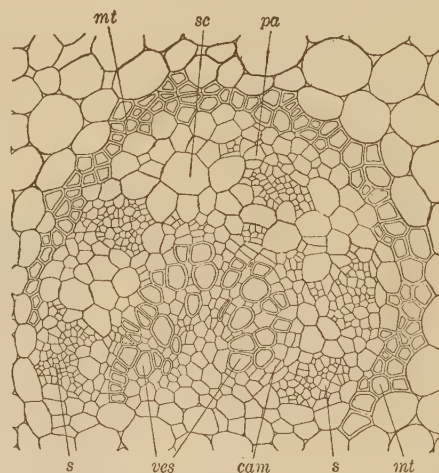


Fig. 21.

Fig. 20. An amphivasal concentric bundle on the extremity of dorsal arc in slender part of petiole in *A. rufinerve* (ca. $\times 160$). Abbreviations as in Fig. 18.

Fig. 21. A crescentic bundle on the extremity of dorsal arc in slender part of petiole in *A. rufinerve* (ca. $\times 160$). Abbreviations as in Fig. 18.

1) L. A. BOODLE (1900, p. 46), in his anatomical studies on the stele of the rhizome of *Hymenophyllum tunbridgense* SMITH, wrote: "The stele has a phloem ring, which may be called continuous, but which tends to have larger elements on the upper side than on the lower, and is more liable to interruption on the lower side. The xylem is monarch, with the protoxylem on the lower side. If the phloem were not developed on the lower side, the result would be a collateral bundle. To signify this, it is convenient to employ a special term for the type of structure found in *Hymenophyllum tunbridgense*, and the term sub-collateral is suggested." His term "sub-collateral" may also apply to the case of *A. rufinerve*, so far as the relative position of xylem and phloem is concerned.

case in which the phloem ring surrounds the crescentic xylem, showing a sub-collateral structure (*A. rufinerve*, Fig. 22).

B. Medullary bundle system

In the foregoing articles we have considered the fundamental vascular system which may be said to consist of a comparatively small number of types, although not infrequently the presence of medullary bundles somewhat complicates the vascular system. These bundles occur in a number of ways, for example, in a certain species, they form at the petiolar base and run through the whole slender part of the petiole, while sometimes, the system becomes more complicated through the addition of new medullary bundles at the petiolar top. It is quite common, even when they are not formed at the petiolar base, that is, when there are no such bundles in the slender part of the petiole, for them to still arise from the fundamental vascular system at the petiolar top. Moreover, in all the cases just mentioned, they are, at the height where the vascular

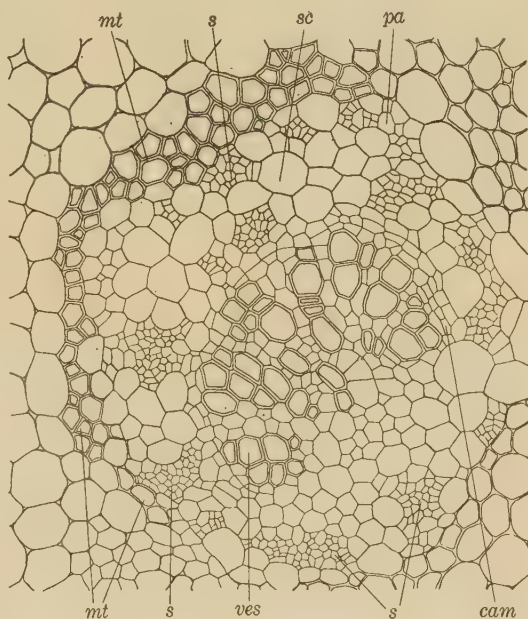


Fig. 22. A sub-collateral bundle on extremity of dorsal arc in slender part of petiole in *A. rufinerve* (ca. $\times 180$). Abbreviations as in Fig. 18.

circle of palmate nerves or petiolules are formed, either totally inserted into a few definite parts of each vascular circle, or partly inserted into the vascular circle, and partly remaining as medullary bundles in the nerves or petiolules, all of which seem to offer some important suggestions with respect to the fact that species belonging to a certain number of intimately allied sections represent almost the same conditions. On the other hand, as the consequence of frequent division, fusion, translocation, twisting, and anastomosing in the formational processes of the medullary bundles at the petiolar base or top, they often show some noteworthy structures.

Although, it is of course difficult to treat these bundles quite apart from the fundamental vascular system, I shall however deal with the system of these bundles separately from the former ones under the "medullary bundle system" both for ease of understanding and for emphasising the above mentioned important characters.

a. Medullary bundle system in the petiolar base and the slender part, and its structure. In some of the species that were observed in the present study a single or a few medullary bundles were found in the slender part of the petiole. In *A. parviflorum*, *A. distylum*, *A. carpinifolium*, *A. negundo*, *A. cissifolium*, *A. dasycarpum* and *A. pseudo-platanus* such bundles are always observed, while in *A. Heyhachii* and *A. pycnatum* var. *rubrum*, they were rarely wanting.¹⁾ In *A. japonicum* also, the presence of these bundles is very rare. The sizes of the medullary bundles differ to a certain extent even in one and the same species, and sometimes, especially in that of the single medullary bundle, its size often far exceeds that of the bundles on the dorsal arc. Even when there are a few medullary bundles, the median one is usually much larger than the others. But in *A. dasycarpum*, a fairly large number of medullary bundles are often of almost the same size. We shall now first describe the structure of these large medullary bundles. Although in their structure they often, at a glance, resemble so much the bundles on the dorsal arc, close observation discloses some interesting facts. As a good example, such a medullary bundle in the slender part of the petiole of *A. pycnatum* var. *rubrum* is shown in Fig. 24, A. At a glance it looks like a collateral, the xylem part on the ventral side consisting of several rows of vessels and the phloem part being situated on the dorsal. In contrast to the normal arrangement of the xylem, however, one can easily see that in the phloem the large elements, chiefly of parenchyma, are situated in the middle surrounded by small elements, chiefly of sieve-tubes and companion cells, arranged in a circle. It clearly differs from the typical collateral situation. In fact, there are some cases in which a few slightly more conspicuous xylem elements are developed not only on the ventral, but also on the dorsal side of such a phloem ring; examples being *A. cissifolium* and *A. Heyhachii*. A more conspicuous example is often found

1) The presence of the medullary bundles in the petiolar base and in the slender part in *A. pseudo-platanus*, *A. macrophyllum*, *A. negundo* and *A. mexicanum* was reported by C. DE CANDOLLE (1879). Those in the first species have also been described by COL (1904) (cf. p. 23).

in *A. pseudo-platanus* as shown in Fig. 23, B, in which the dorsal xylem develops markedly and the xylem elements to almost the same extent, in the ventral part.¹⁾

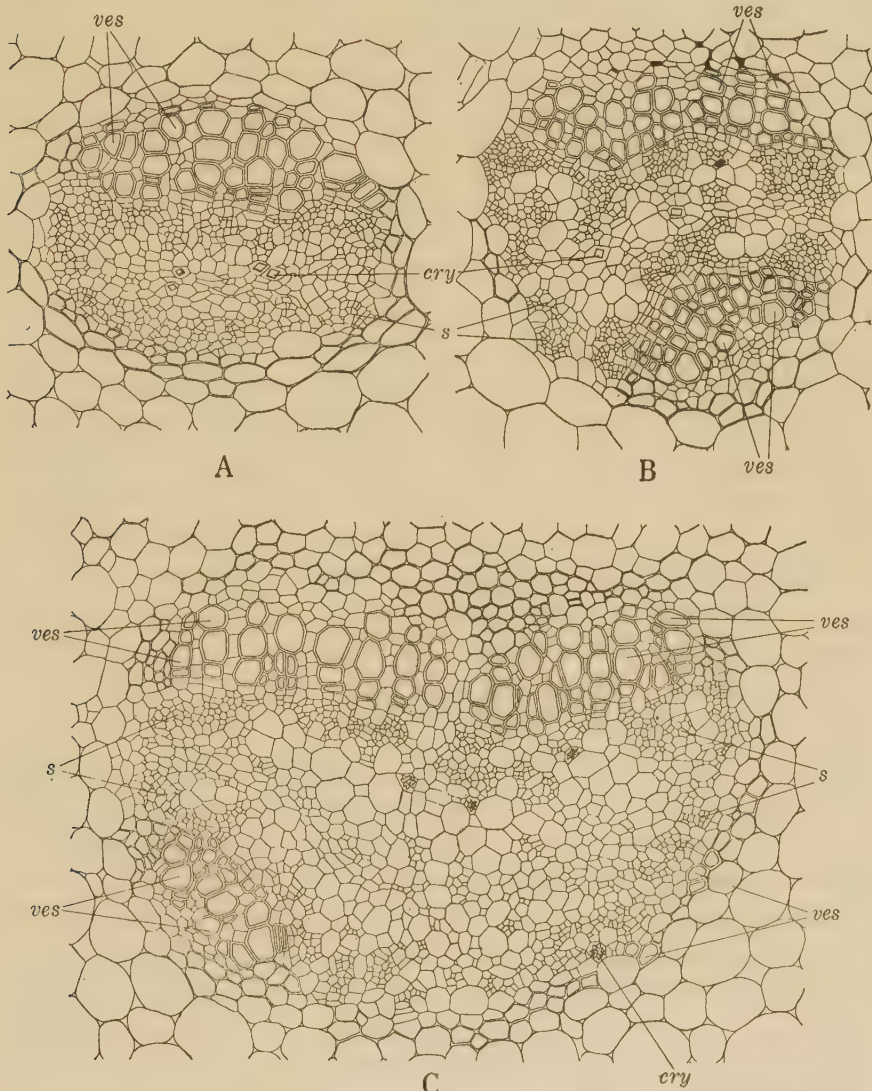


Fig. 23. Medullary bundles in slender part of petiole: A ($\times 150$), *A. pycnatum* var. *rubrum*; B ($\times 150$), *A. pseudo-platanus*; C ($\times 150$), *A. parviflorum*. Explanations in text. Abbreviations as in Fig. 18.

1) COL (1904) pointed out that in *Acer pseudo-platanus*, the number of medullary bundles was variable and in a case of three, "....., le médian est concentrique avec liber central" (p. 137). In his figure (p. 144, fig. XXII-5), the xylem part is diagrammatically drawn as a continuous ring, a form which however, I did not meet with in the present study.

The circular arrangement of the sieve-tube groups is also observed in *A. parviflorum* and *A. distylum*, in which a few small sieve-tube groups are frequently scattered within the phloem ring. Fig. 23, C shows the medullary bundle in *A. parviflorum*. On the upper side of the phloem ring, one may see the xylem consisting of about fifteen rows of vessels, while on the lower lateral sides, a few xylem elements are seen. The xylem elements on the dorsal side, however, are often altogether absent.

Now, in order to gain a more accurate knowledge of these complicated structures, it may be advisable that we consider the manner of formation of such a medullary bundle at the petiolar base. I shall describe its formation in *A. parviflorum* as an example. Fig. 24, A-G, show transverse sections at successive heights of the petiolar base where the medullary bundles form (cf. Fig. 2, C-F). At the petiolar base both lateral traces divide into two; the median trace and four lateral ones thus formed, each in the form of C with incurved ends, being arranged in an arc. Each incurved end of these five bundles then detaches and migrates to the chord of the arc; these bundles, i. e., the components of the ventral bundle, showing an inversed orientation compared with those on the arc with respect to the relative positions of xylem and phloem. Immediately higher up, the margins of each bundle on the chord fold into the pith, when finally they detach and migrate into the pith. After going through twisting and fusion, they form several medullary bundles, namely, five bundles $a+a'$, $b+c$, $b'+c'$, $d+e$ and $d'+e'$, in the figures (Fig. 24, A-D). Since every one of these bundles form by the same process, I shall describe one of the medullary bundles ($a+a'$). At first from the margins of the bundle v_1 and v_1' which are translocated from the original median trace, small bundles (a and a') successively form inwards, when they are succeeded by a few small bundles consisting of both xylem and phloem elements, the latter then being fused the one with the other, xylem to xylem and phloem to phloem, so as to form a phloem ring with xylem elements on its upper side (Fig. 24, C, in which the circular arrangement of the phloem is indicated by the broken line). Slightly higher up, the medullary bundles, after going through the same process, are fused to form a large medullary bundle so as to retain the circular arrangement of phloem. Usually the xylem elements are mostly situated on the upper side, but some of them may often be found on the lateral or lower side of the phloem ring and a few phloem strands also isolated within the ring. Thus the medullary bundle shown in Fig. 23, C is formed (Fig. 24, G). The case in which a certain number of medullary bundles in the base of the

petiole fuse into a bundle in the slender part is seen, besides the species just mentioned, in *A. negundo* and *A. pseudo-platanus*. In other examples, the medullary bundle is formed only of parts corresponding to $a+a'$ in *A. parviflorum*. In *A. distylum*, there joins, rarely, to the corresponding bundle $a+a'$, smaller ones from certain bundles on the dorsal arc which however are essentially the same as $b+c$, $d+e$, etc., in *A. parviflorum*, for the reason that the very bundles that produce $b+c$, $d+e$, etc., originated from the arc bundle lower down in the petiolar base. The medullary bundles in *A. japonicum* and *A. Heyhachii* are formed, sometimes, by this process.

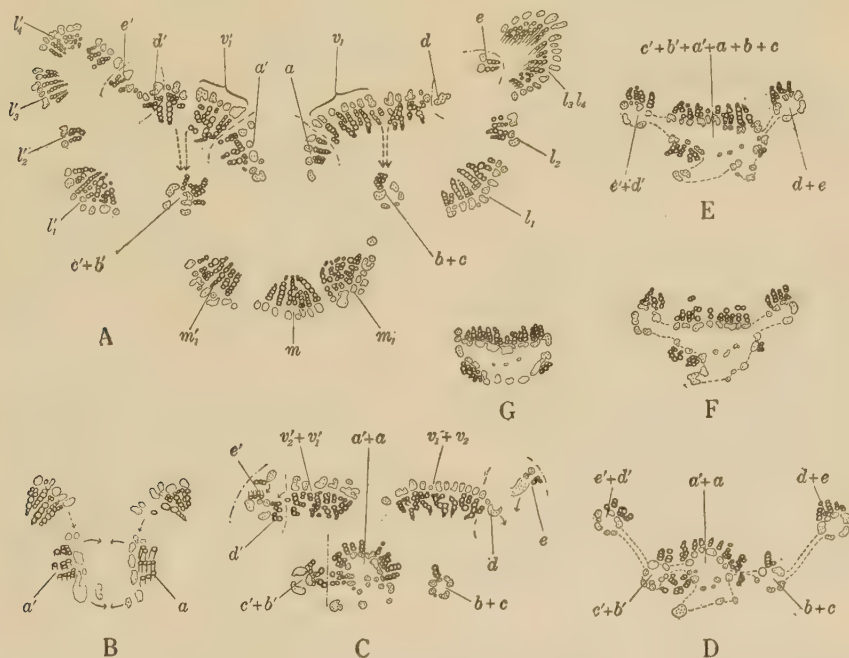


Fig. 24. *A. parviflorum* (A-G, $\times 30$): Complicated vascular course in petiolar base (A-F), the medullary bundle in slender part of petiole (G) has formed. Detailed structure of fig. G shown in Fig. 23, C. Explanations in text.

In some instances, a few medullary bundles situated on the outer side, such as $d+e$, $d'+e'$, etc., remain separated throughout the whole slender part. In such bundles, the circular arrangement of phloem is also retained throughout their whole course, the woody elements being generally few or often entirely absent. Besides a large medullary bundle, smaller ones are often observed in *A. japonicum*, *A. cissifolium*, *A. negundo*, etc.

A similar structure of the medullary bundle is also to be observed in the

petioles of certain species of other families. In my last work on Leguminosæ (1934), are described some species, e. g., *Bauhinia japonica* (Text-fig. 14; Pl. V, fig. 10), *Cercis chinensis* (Text-fig. 15, D; Pl. V, fig. 13), etc., in which the medullary bundle in the slender part of the petiole shows a form of ringlet. This ringlet consists of a continuous phloem ring usually surrounded by a xylem ring developed almost uniformly along the former. In *Sterculia platani-folia* L. fil., also, I have often seen a medullary bundle in which the phloem shows a continuous, more or less laterally flattened ring; the woody elements as usual developed conspicuously on the ventral and poorly on the dorsal side of the former ring.

b. Medullary bundles in the petiolar top and in the basal part of the nerves or petiolules, and their structure. In the petiolar top, the formation of the medullary bundles, even when they do not occur at the petiolar base, may often be observed. One may therefore roughly divide the formation of such bundles at the petiolar top into the following two cases: (1) whereas no medullary bundles are found in the petiolar base and slender part, they are found at the petiolar top, and (2) their formation takes place already at the petiolar base, and as far as my present observation goes, a single or a few medullary bundles are always seen throughout the slender part, while at the petiolar top the new medullary bundles may or may not appear. In the present article these cases will be treated together, as also their situations in the basal part of the nerves or petiolules.

1. The case in which the medullary bundles form only at the petiolar top is quite common in aceraceous species. Although usually arranged in a complete arc, they are sometimes scattered. This condition may again divide into several cases when we consider their origin from the vascular circle. In some species, they arise chiefly from the margins of the bundles on the dorsal arc, especially from those on the lateral side, and a small part of them often or rarely from the ventral bundle, mostly from both margins, but rarely by invagination from the middle part (*A. capillipes*, Fig. 6, J, K; *A. Oliverianum* var. *Nakaharæ*, Fig. 11, E; *A. campestre*, Fig. 15, B; etc.). As to the total number of these bundles thus formed it is fairly, or very, small in species of § *Macrantha*, § *Palmatoidea*, some of § *Spicata* (*A. trifidum* and *A. trifidum* var. *formosanum*), and some of § *Palmata* (*A. amœnum*, *A. ornatum* and *A. ornatum* var. *Matsumuræ*), while it is fairly, or very, large in species of § *Arguta*, *A. Oliverianum* var. *Nakaharæ* (§ *Spicata*), some of § *Palmata*, especially in *A. Shirasawanum*, *A. tenuifolium*, *A. japonicum*, and § *Campestris*.

In some others, on the other hand, they are chiefly derived from the ventral bundle to which has joined a small part from the dorsal bundles (*A. ukurunduense*, Fig. 10, D-F; and *A. oblongum*, Fig. 14, A).¹⁾ Moreover, in *A. nikoense*, *A. diabolicum* (Fig. 15, G: medullary bundles are somewhat scattered) and in species of § *Platanoidea*, they arise from both dorsal and ventral bundles, their number in the former two species being numerous.

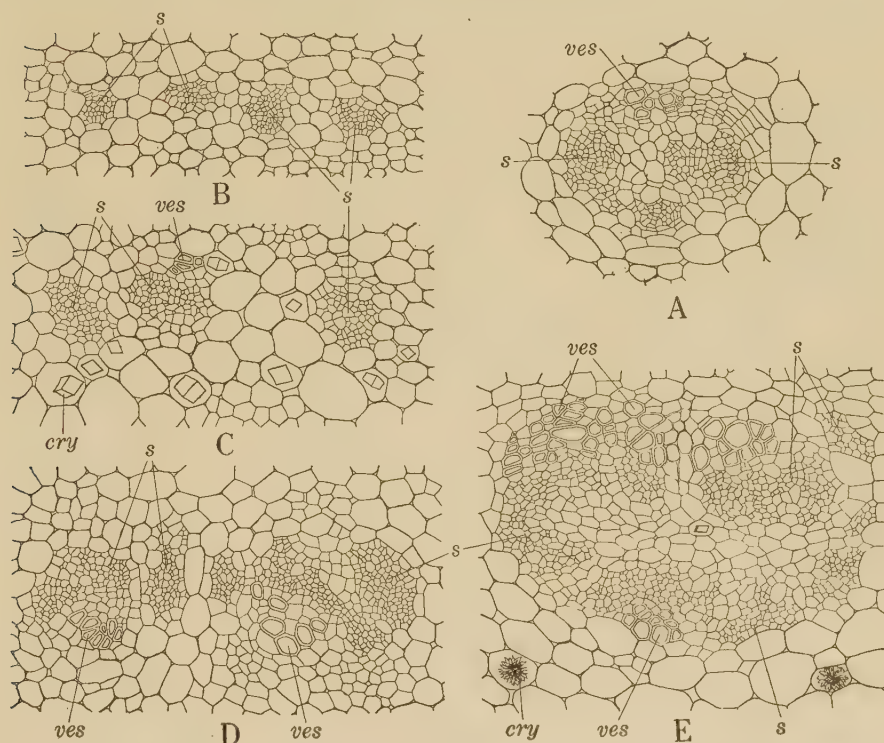


Fig. 25. Some examples of medullary bundles at petiolar top, showing their structures: A ($\times 150$), *A. rufinerve*; B ($\times 150$), *A. Shirasavanum*; C ($\times 150$), *A. formosum*; D ($\times 150$), *A. diabolicum*; E ($\times 150$), *A. ukurunduense*. Explanations in text. Abbreviations as in Fig. 18.

These medullary bundles thus formed are mostly quite minute, the phloem part being fairly well developed and the xylem elements poorly so. They have no definite orientation owing to frequent division, fusion, translocation and twisting in the course of their formation. These bundles in a number of

1) *A. platanoides* described by COL (1904) seems to belong in this category. According to his illustration (Fig. XXII, 9-11), these medullary bundles appear to have a considerably well-developed xylem part.

species are shown in Fig. 25. The medullary bundle in *A. rufinerve* (fig. A) is formed near the petiolar top from a pair of special bundles on the dorsal arc (x and x' in Fig. 6, C-E; see also descriptions on pp. 12-14). In the illustrated example are seen only a few woody elements (*ves*) in contrast to the phloem part, which consists of three fairly large groups of sieve-tube elements. The components of the arc of medullary bundles in species of § *Palmatoidea*, § *Arguta*, § *Palmata*, etc., and in each of the scattered medullary bundles in *A. diabolicum*, etc., consist largely of one or two bundles of sieve-tube elements accompanied by either none or a small number of xylem elements, consisting mostly of minute vessels. In fig. B and C is shown a part of the medullary bundle arc in *A. Shirasawanum* and *A. formosum*, in the former of which are four bundles that consist only of sieve-tube elements, while in the latter example, the median one has a few vessels. A part of the scattered medullary bundles in *A. diabolicum* is also shown in fig. D, in which are several sieve-tube groups, two of them having several xylem elements. In *A. ukurunduense*, (cf. p. 21 and Fig. 10, D-F), fairly large medullary bundles are formed from both folded margins of the ventral bundle. One of these bundles is shown in fig. E (one of the bundles shown in Fig. 10, E), the sieve-tube groups being arranged on a ring as in the case of that in the slender part in some of the other species. The xylem elements are also few. In the illustrated example, about twenty and seven xylem elements are developed respectively on the upper and lower sides of the phloem ring.

2. a) The case of the medullary bundles forming at the petiolar base with none freshly added at the petiolar top is observed in *A. parviflorum*, *A. distylum*, *A. cissifolium*, *A. pycnatum* var. *rubrum* (rarely medullary bundles altogether absent) and in *A. dasycarpum*. In these species, the medullary bundles in the slender part are gradually flattened near the petiolar top, when finally there is formed, through its division, an arc consisting of three (e. g., *A. distylum*, Fig. 3, F) or more bundles (e. g., *A. parviflorum*, Fig. G, H). In these divided bundles, the xylem elements usually develop well compared with the former case and they usually retain the ring arrangement of the sieve-tube elements. It may therefore be said that the formation of the medullary bundle arc, disregarding the number of formed bundles, progresses in direction opposite to that of their formation at the petiolar base (cf. Fig. 24, A-G, *A. parviflorum*).

b) The case in which the formation of the medullary bundles is observed at the petiolar base, and new ones are added at the petiolar top. This is

observed in *A. negundo* (Fig. 8, J-O), *A. pseudo-platanus*¹⁾ (Fig. 11, I, J, and Fig. 12, A-I), *A. Heyhachii* (Fig. 13, M, N) and, rarely, in *A. japonicum*. In these species the behaviour of the medullary bundles at the petiolar base and the slender part is exactly the same as in the former case (2-a), while those formed at the petiolar top show the same behaviour and structural features as in case 1. In the former two species (*A. negundo* and *A. pseudo-platanus*), their courses in the petiolar top are somewhat complicated as shown respectively in Fig. 8, J-O (cf. descriptions on pp. 16-18) and Fig. 12, A-H (cf. descriptions on pp. 22-23).

We shall now consider the behaviour of medullary bundles in the vascular circle of the basal parts of the nerves or petiolules. In species with medullary bundles at the petiolar top only, they are inserted in most cases into a few definite parts²⁾ of each vascular circle of nerves or petiolules (species of § *Macrantha*, e. g., *A. rufinerve*, Fig. 6, G, H; § *Palmatoidea*; § *Arguta*; § *Palmata*; § *Platanoides*; etc.), and although in a few species, the larger parts of the medullary bundle are inserted into the circle as just mentioned, a small part remains in the circle of each nerve or petiolule (*A. ukurunduense*, Fig. 10, I; *A. oblongum*; *A. nikoense*, Fig. 14, F; *A. diabolicum*; and very rarely in *A. trifidum* var. *formosanum*) or only in the median or in a certain number of nerves or petiolules (*A. campestre*, rarely in *A. trifidum* var. *formosanum* and *A. Miyabei*). In most species with medullary bundles at the petiolar base, a part of them remains in the vascular circle of each nerve or petiolule (*A. parviflorum*, Fig. 2, L, M; *A. cissifolium*, Fig. 9, B; *A. pycnatum* var. *rubrum*; *A. dasycarpum*; *A. negundo*, Fig. 8, O, Q; and *A. pseudo-platanus*, Fig. 11, J), or in the median or in a certain number of nerves or petiolules (*A. distylum*, Fig. 3, H, I; rarely in *A. japonicum* and *A. Heyhachii*).

The structure of a medullary bundle in the basal part of nerves or petiolules is generally collateral. In some species belonging in category 1. in this article, it is, as usual, minute and consists mainly of the phloem part. In *A. ukurunduense*, the condition of the phloem ring with the xylem on one of its sides is often retained, while in each petiolule of *A. nikoense*, there are usually from one to three medullary bundles each showing an amphivasal concentric struc-

1) Since according to COL (1904), contrary to my present observation, the medullary bundles in this species do not seem to form at the petiolar top, his case comes in the former category 2-a.

2) On the parts where these medullary bundles insert on the vascular circle of nerve or petiolule, see foot note, p. 40.

ture (Fig. 26). In species belonging in category 2., the structure just mentioned changes, in nerve or petiolule, into collateral in many cases but often the condition of the phloem ring is retained as in the former case (often in *A. parviflorum*, *A. dasycarpum*, etc.). Sometimes the medullary bundles are fused end to end with the ventral bundle of the vascular circle of nerves or petiolules to form a ringlet with the inner xylem and outer phloem (*A. parviflorum*, Fig. 2, M, see nerve n_1 ; *A. distylum*, Fig. 3, I; *A. negundo*, Fig. 8, O, in a petiolule on left-hand side of figure, etc.).

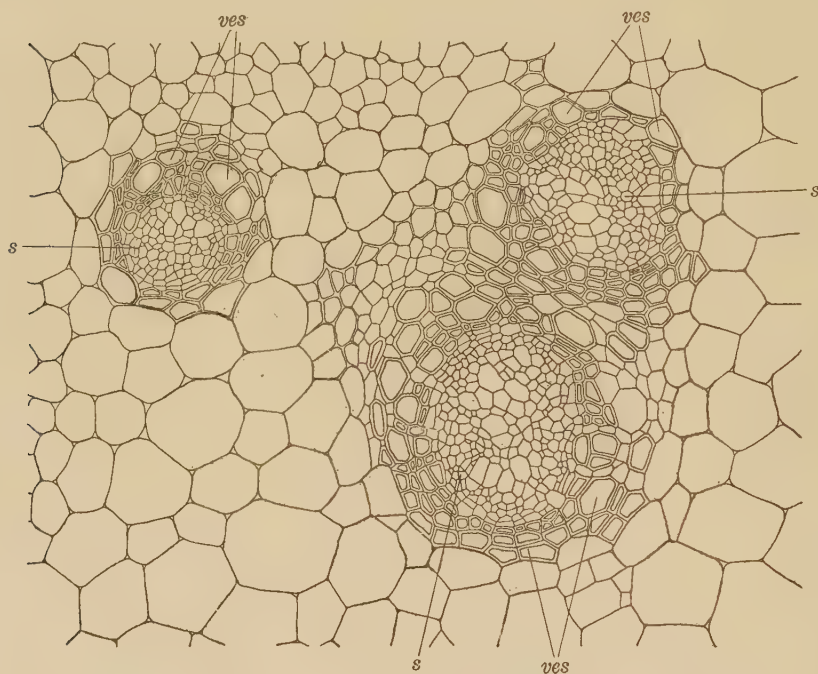


Fig. 26. Amphivasal concentric medullary bundles in petiolule of *A. nikoense* ($\times 180$). Abbreviations as in Fig. 18.

As a matter of information and to aid in making comparisons, I might say that a similar formation of medullary bundles at the petiolar top has also been observed in some species of Leguminosæ described by me (1934). For example, in *Lupinus hirsutus* (pp. 272-273; and Text-fig. 25, and Pl. VIII, fig. 44), a pair of small amphivasal concentric medullary bundles arises from the lateral ventral part of the vascular circle near the petiolar top where they join the fan-like vascular entanglements at the petiolar top; in *Saraca indica* (p. 246, Text-fig. 10), several amphivasal concentric medullary bundles form by

invagination from the ventral part of the vascular ring at each nodule, being partly inserted into the vascular circle of the petiolule of the lateral leaflet, which partly serves as medullary bundle in the petiolule and partly remains in the rachis, the latter soon returning to insert into the ventral side of the vascular ring of the rachis at a point a little above the nodule. In *Erythrophleum guineense* (pp. 244–246; Text-figs. 8, 9), a pair of amphivasal concentric medullary bundles invaginate from the lateral ventral part of the vascular ring at each nodule and place themselves at a definite part of the vascular circle of the petiolule. These conditions in Leguminosæ seem to show close resemblance to the cases in the present observation. Also among the leguminous species, *Amherstia nobilis* (pp. 247–248; Text-fig. 11) and in some belonging to the tribe Phaseoleæ (pp. 300–309; Text-figs. 42–44), e. g., *Glycine Soja*, *Erythrina crista-galli*, *Erythrina indica*, *Apios Fortunei*, *Mucuna ferruginea*, *Pueraria Thunbergiana* and *Dolichos Lablab*, the medullary bundles form at the very base of the petiolule, their presence being confined only to a part of the petiolule length.

c. Distribution of diverse medullary bundle systems among 16 sections.

Regarding the question as to whether the formation of medullary bundles in the petiolar base and top occur or not¹⁾, and whether they are present or absent in the basal part of nerves or petiolules,²⁾ their distribution in 16 sections of *Acer* is shown in Tab. II.

As will be seen from this table, of the 42 species comprised in 16 sections, case *A* is always represented by 3 species and, rarely, by 3 species; *B-1-i* always by 24; *B-1-ii* always by 6 and, rarely, by 1; *B-2-a* always by 6; *B-2-b-i* always by 1 and, rarely, by 1; and *B-2-b-ii* always by 2 and, rarely, by 2. Thus the presence of medullary bundles at the petiolar top is seen in 33 species, including cases *B-1-i*, *B-1-ii*, *B-2-b-i* and *B-2-b-ii* (duplications under ordinary conditions have been deducted). Further, cases in which the medullary bundles form at the petiolar top only (*B-1-i* and *ii*), at the petiolar base only (*B-2-a*), and at both these part (*B-2-b-i* and *ii*) are treated together, there being 39 species showing these conditions, with the result that medullary bundles are observed in about 93 per cent of all the species investigated, which shows the importance of the medullary bundles in the position of the petiolar vascular system in the aceraceous species.

1) Here the various ways in which the bundles form at the petiolar tops and bases are not considered.

2) Including cases—they are present in one, in some, or in all the nerves or petiolules.

Tab. II. The various medullary bundle systems in the 16 sections

A. With no medullary bundles anywhere.¹⁾

B. With medullary bundles.

1. No medullary bundles at the petiolar base, but only at the petiolar top: *i*, no medullary bundles at the basal part of nerves or petiolules; *ii*, with medullary bundles at the basal part of nerves or petiolules.
2. Medullary bundles at the base, the slender part, and on the top of the petiole: *a*, no medullary bundles freshly issue at the petiolar top; *b*, medullary bundles issue afresh at the petiolar top; *i*, no medullary bundles at the basal part of nerves or petiolules; *ii*, medullary bundles at the basal part of nerves or petiolules.

Numbers in parenthesis refer to rare cases, which are counted in numbers without parenthesis.

Sections	A	B					Remarks
		1		2			
		i	ii	a	b-i	b-ii	
1. <i>Parviflora</i>	1 ¹⁾			1			1) <i>A. cratoegifolium</i>
2. <i>Indivisa</i>				1			
3. <i>Carpinifolia</i>				1			
4. <i>Macrantha</i>		3					
5. <i>Palmatoidea</i>		2					
6. <i>Arguta</i>		1					
7. <i>Negundo</i>	(1) ²⁾					1	2) <i>A. pycnatum</i> var. <i>rubrum</i> 3) See explanation in text 4) <i>A. Heyhachii</i> 5) <i>A. japonicum</i> 6) <i>A. japonicum</i> and <i>Heyhachii</i> 7) <i>A. laevigatum</i>
8. <i>Cissifolia</i>				1			
9. <i>Rubra</i>				2			
10. <i>Spicata</i>		1(2) ³⁾	2	2		1	
11. <i>Palmata</i>			9		1 ⁴⁾ (1) ⁵⁾	(2) ⁶⁾	
12. <i>Integrifolia</i>	1 ⁷⁾		1				
13. <i>Trifoliata</i>			1				
14. <i>Campestris</i>			1				
15. <i>Platanoidea</i>			7	(1) ⁸⁾			
16. <i>Diabolica</i>				1			
Total	3(3)	24	6(1)	6	1(1)	2(2)	

1) According to COL (1904, p. 139), *A. monspessulanum* represents this condition.

Rare cases, on the other hand, are not considered, their distribution among 16 sections being however as follows: species of § *Parviflora*, § *Carpinifolia*, § *Cissifolia*, and § *Rubra* represent condition *B-2-a*; species of § *Macrantha*, § *Palmatoidea*, § *Arguta*, § *Palmata* (except *A. Heyhachii*), and § *Platanoidea*, *B-1-i*; *A. negundo* (§ *Negundo*), *B-2-b-ii*; species of § *Trifoliata*, § *Campestris* and § *Diabolica* represent *B-1-ii*; § *Indivisa*, *A. cratægifolium*, shows *A*, and *A. distylum* represent *B-2-a*; § *Integrifolia*, *A. lævigatum* shows *A*, and *A. oblongum*, *B-1-ii*; while in § *Spicata* several conditions are shown by such species as *A. aizuense*, *A*, *A. trifidum* var. *Nakaharæ*, *B-1-i*, *A. trifidum* var. *formosanum* and *A. ukuruduense*, *B-1-ii*, and *A. pseudo-platanus*, *B-2-b-i*.

As to the presence of medullary bundles in the basal part of the nerves or petiioles, they are always present in representatives of *B-2-a* and *b*, excepting the very rare case of *A. japonicum* and many cases of *A. Heyhachii*; while in those of *B-1*, cases of presence and absence of them occur with like frequency (cf. Tab. III). Thus, though there are a few exceptions, it will easily be seen that species belonging to one and the same section mostly represent the same or closely allied conditions, while the said condition may also obtain in a group including a certain number of closely allied sections.

C. Bifacial and unifacial structure of petiole

In his Systematische Anatomie der Dicotyledonen, SOLEREDER (1899, p. 270) wrote „Der Blattbau ist bei allen bifazial mit Ausnahme von *A. negundo*, dessen Blatt centrisch gebaut ist.“ The results of my present observations show however some interesting facts in the structure of petioles in that the margins of the petiolar base persist throughout the whole length of the petiole to form the ridges and groove of the petiole, and the margins are continued directly to the margins of the lamina; or the margins are retained separately but obscured by the cylindrical feature of the slender part, so that the laminal margins arise at the petiolar top from two points independently; or they converge on the median line of the ventral side of the petiole, the laminal margins diverging at the petiolar top at a point on the median line, etc. The former two may represent the so-called “bifacial structure” and the latter the “unifacial structure.” In a few examples, however, it was observed that unifaciality is confined to the region that is transitional between the petiolar base and the slender part.

As a typical example of bifacial structure, a part of the petiolar base and

top of *A. rufinerve* is shown (Fig. 27, A, B). The margins (r and r') of the petiolar base continue through the slender part as ridges (cf. Fig. 6, D: middle of petiole) as far as the petiolar top, and further transform into the margins of the lamina. Thus the margin of ridges define the morphological ventral and dorsal surfaces of a petiole—a condition that is observed, besides *A. rufinerve*, in *A. cratægifolium*, *A. carpinifolium*, *A. capillipes*, *A. rubescens*, *A. micranthum*, *A. Tschonoskii*, *A. argutum*, *A. trifidum*, *A. trifidum* var. *formosanum*, *A. aizuense*, *A. pseudo-platanus*, and in *A. laevigatum*. Although in another example of the bifacial structure of *A. diabolicum* (Fig. 27, C, D), the margins and

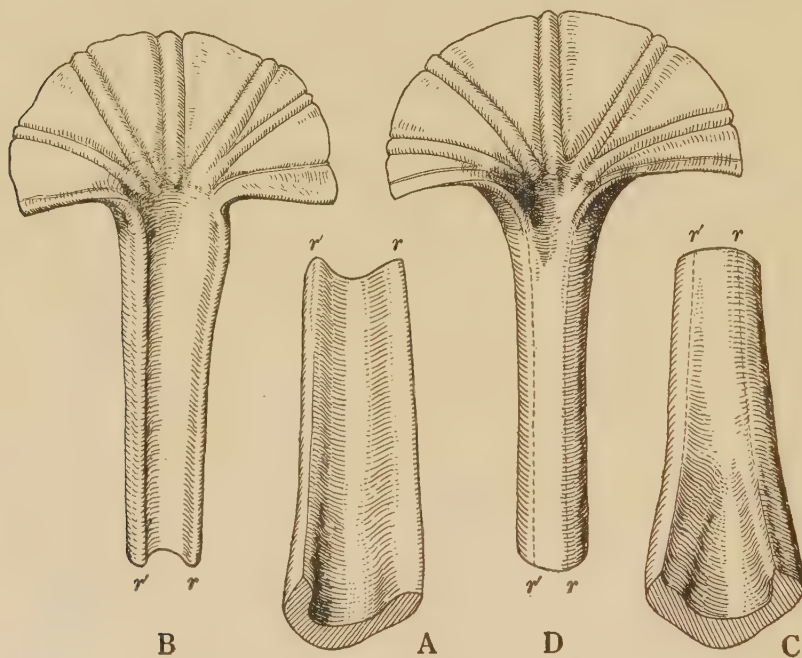


Fig. 27. Two examples of bifacial petiole: A, B, ($\times 5$), *A. rufinerve*; C, D ($\times 5$), *A. diabolicum*. Explanations in text.

ventral groove are seen at the petiolar base as in the case of *A. rufinerve*, the margins soon become obscured by disappearance of the groove (fig. C). At the same time, the margins of the lamina arise afresh at the petiolar top (Fig. D). Upon comparing this case with that of *A. rufinerve*, we may be assured that the original margins defining both surfaces of the petiole correspond, strictly speaking, to the broken lines indicated by r and r' in the figures. Besides the said species, this condition is found in *A. parviflorum*, *A. pycnatum* var. *rubrum*, *A. dasycarpum* and *A. campestre*.

Conditions intermediate between the two last-mentioned are represented by *A. distylum*, *A. ukurunduense*, *A. nikoense* and *A. Miyabei*.

In some species, the margins of the petiolar base converge gradually or more or less abruptly above the base into the ventral median line of the petiole to form an unifacial structure. In almost all such species, unifaciality is retained throughout the whole length of the slender part, while in a few

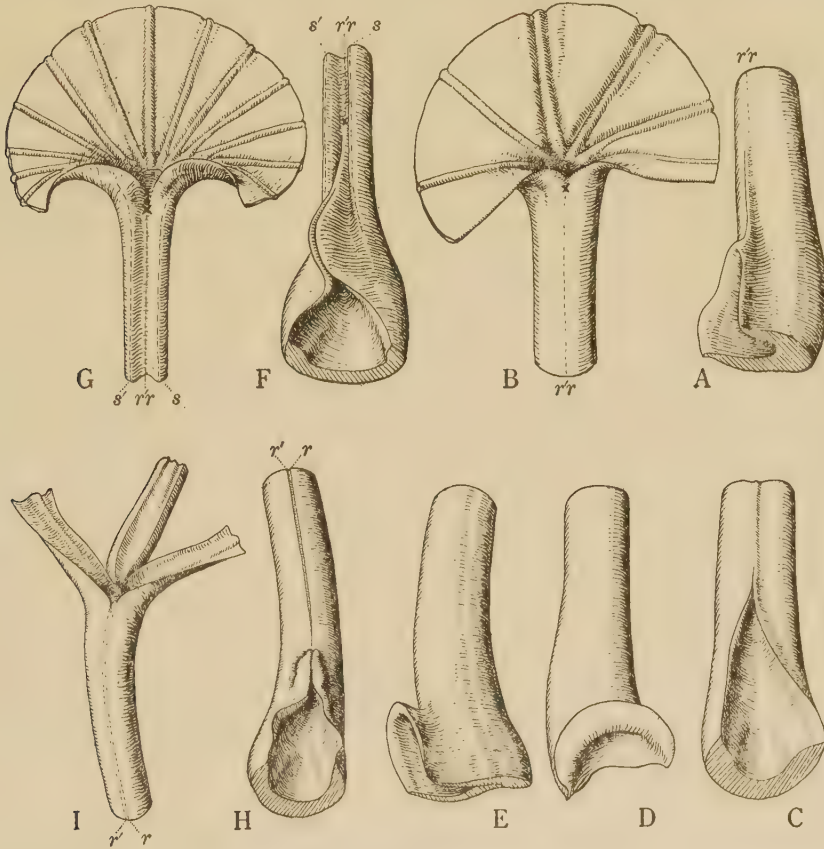


Fig. 28. Examples of unifacial petiole: A-E ($\times 4$), *A. mono*; F, G ($\times 5$), *A. Shirasawanum*; H, I ($\times 5$), *A. cissifolium*. Explanations in text.

cases it is not so, but soon assumes the subunifacial condition. As an excellent example of unifaciality being retained throughout the whole length, the petiolar base and top of *A. mono* are shown (Fig. 28, A-E). The most common condition in the petiolar base is shown in fig. A. One may easily see that the unifacial structure is formed by gradual convergence of the margins of the petiolar base to the ventral median line of the petiole near the petiolar

base. In other examples of the same species, however, convergence of the margins takes place either more gradually (fig. C) or rather abruptly (figs. D, E: D, ventral view; E, side view). In the last case, the fused margins bend over toward the ventral surface of the petiole, presenting the appearance of axillary stipules of certain plants. Since at all events, the slender part is cylindrical and unifaciality continues until the margins of the lamina diverge from the ventral median line at the petiolar top (fig. E), it is difficult when only the slender parts are compared to distinguish the cylindrical petiole with unifacial structure in this species from the cylindrical one with bifacial structure in other species, the distinction lying only in the presence or absence of the convergence and divergence of the margins in the petiolar base and top. Besides *A. mono*, its varieties represent this condition. *A. Mayrii* and *A. amœnum* are also often representatives of this type, although they rarely show that condition intermediate between that of *A. mono* and that of *A. Shirasawanum*, as will be referred to later.

A. Shirasawanum also exhibits unifacial structure (Fig. 28, F, G). Although the margins of the petiolar base fuse by gradual approach, it differs from *A. mono* in the formation of new ridges on the ventral-lateral sides (fig. F), so that the margins of ridges in the slender part do not correspond to the original margins in the petiolar base, they being secondary ones, the original margins corresponding to the median line of the groove. As a matter of fact, at the petiolar top, margins of lamina arise from the ventral median line regardless of the secondary ridges (fig. G). Thus, the unifacial slender part with ridges and groove can scarcely be distinguished from that in bifacial structure when the slender parts alone are compared. *A. Sieboldianum*, *A. Sieboldianum* var. *microphyllum*, *A. tenuifolium*, *A. japonicum*, *A. Heyhachii* (Fig. 13, K, L, M), *A. formosum*, *A. ornatum* and *A. ornatum* var. *Matsumurae* represent the allied structures.

Although the unifacial structure in *A. cissifolium* forms in the same way as in *A. mono*, it soon takes on the subunifacial structure which continues through the slender part (Fig. 28, H, I). The same thing is observed in *A. negundo*.

Along with unifacial structure, we meet with a certain number of species that have a cavity of more or less depth formed for the intra-petiolar bud,¹⁾—a

1) This condition is the same as that in *Styphnolobium japonicum*, *Robinia pseudacacia*, which were treated by the author in his studies on leguminous leaves.

condition observed in *A. Oliverianum* var. *Nakaharæ* (rarely), *A. negundo* (Fig. 8. A, B, C), *A. Sieboldianum* and *A. Sieboldianum* var. *microphyllum*. In *A. japonicum*, *A. Heyhachii*, *A. tenuifolium*, etc., the margins approach each other preparatory to their fusion to form a chamber in which the axillary bud is enclosed. As the bud develops, it exposes itself outside the chamber.

Here, we have an important fact that must be considered with caution on the relationship between these external morphological features and the vascular systems in the said organ. TROLL has repeatedly maintained in his morphological works on the „doppelspreitige Blätter“ (1932, a), „schildförmige Blätter“ (1932, b), sporangium bearing leaves in *Ophioglossum* and *Botrychium* (1933), etc., that the petioles of these leaves have an inevitable casual dependence on „unifacial structure.“ On the differences between unifacial (not only of the above mentioned special forms, but also in the normal situation of lamina and petiole) and bifacial structures, he wrote (1932, b, p. 163): „Die Unterscheidungen zwischen bifazialen und unifazialen Stielen ist nicht immer einfach durchzuführen. Wenn auch erstere im allgemeinen dorsiventral, die unifazialen Stiele dagegen rund sind, so gibt es doch auf beiden Seiten Ausnahmen, nämlich runde bifaziale bzw. dorsiventrals (d. h. sekundär abgeflachte) unifaziale Stiele. Die Entscheidung darüber, welche Form des Stielbaues vorliegt, kann vielfach erst auf Grund des Leitbündelverlaufes gefällt werden.“ and, in other part (1933, p. 553), he said, „Am deutlichsten kommt der Unterschied von bifazialen und unifazialen Blattstielbau in der Leitbündelanordnung zum Ausdruck. Wie an anderer Stelle eingehend dargetan wurde (1932, b, p. 163), besitzen Blattstiele einen nach oben offenen Leitbündelbogen. Wo die Oberseite nur schwach entwickelt ist, sind dessen beiden äussersten Stränge einander an genährt, um bei gänzlicher Unterdrückung der Oberseite nicht selten zu einem einzigen Strang zu verschmelzen, der als Ventral medianus den Dorsal medianus oder Mittelnerven des Blattes gegenüberliegt (Abb. 6, IV). Damit hat sich der Leitbündelbogen zu einem Kreis geschlossen, was also ein Ausdruck dafür ist, dass der Stiel aus einem bifazialen Organ zu einem unifazialen geworden ist.“ He stressed the importance of differences between these two structures upon their vascular systems, namely, that unifacial structure is characterized by the fact that both extreme outer ends of the original outermost traces either come closely to each other on the ventral side of the petiole or form a single bundle „Ventralmedianus“ by the fusion of these extreme ends.

I have also hitherto observed, on many species including some that have been

referred to by TROLL, that the correlation between unifacial structure and the character of the vascular system agrees with his contentions. I too have observed that the petiole or stalk of epiascidia that have formed either by transformation of the lamina base in the simple leaves or leaflets in the compound leaves or as an appendage on the dorsal side of the lamina of simple leaves or leaflet in compound ones, always exhibit unifacial structure in its external morphology and that the vascular system in these organs also almost always show conditions agreeing with TROLL's observations (1936).¹⁾

Reverting to the aceraceous species, their vascular system, as one may have already seen from the descriptions in the foregoing articles, is always characterized by a dorsal arc consisting of several separated bundles and a single (or rarely a pair of) large ventral bundles, in the construction of the latter of which, though they do not all form in the same way, is not quite the same as the "Ventralmedianus," but rather shows agreement with the ventral part of the vascular circle in *Aesculus hippocastanum*, *Æ. hippocastanum* f. *digitatum*, or in *Æ. parviflora*, whose petioles have been described by TROLL (1932, b, pp. 164-165) as examples possessing an evident bifacial structure from the view-point of characters of their vascular system. Thus, so far as my present observations go, the characteristic features of the vascular systems concerned with bifacial and unifacial structures can scarcely be recognized.²⁾ To my knowledge, cases of such relation between the vascular system and the external morphological features are very rare. Should they occur, the question as to whether the manifestation ought to be regarded as rare or fairly common seems to owe its answer to further observations on vascular systems in petioles of evident unifacial structure from the standpoint of external morphology.

In Tab. III, the unifacial and bifacial structures in each species are respectively designated by *U* and *B* in column "fa." Upon looking over the

1) An epiascidium formation in some leaves of *Ginkgo biloba*, *Caragana Chamlagu*, *Shiia Sieboldii*, *Corylus heterophylla* var. *japonica*, receives principal treatment. In these species it was observed only in the first named one that a pair of bundles in the slender part of the petiole had changed at the petiolar top into a vascular circle of four bundles, whereas the original extreme ends neither approached each other nor fused with each other.

2) Although in the foregoing article on the vascular system in the petiolar base, there are some slightly different types in the manner of formation of the ventral bundles (cf. pp. 33-36), that these types are altogether independent from these external morphological features may easily be seen by comparing the distribution of the former (cf. pp. 36-37 and Tab. I) with that of the latter. Compare also Tab. III, in which the types of ventral bundle formation are shown with signs *ML*, *M(L)*, *M* in column "VB" and the said external morphological features, shown by *B* and *U* in column "fa."

distribution of these two types among the systematic groups, the bifacial type is seen in all species belonging to subgn. *Intrastaminalia*, and among subgn. *Extrastaminalia*, all species of § *Rubra*, § *Trifoliata*, § *Integrifolia*, § *Campestris*, § *Diabolica*, all species of § *Spicata* excepting *A. Oliverianum* var. *Nakaharæ*, and only in *A. Miyabei* in § *Platanoidea*, while the unifacial type is represented by all species of § *Negundo*, § *Cissifolia*, § *Palmata*, all of § *Platanoidea* excepting *A. Miyabei*, and one of § *Spicata* (*A. Oliverianum* var. *Nakaharæ*).

It will thus be seen that bifacial structure prevails in species of both subgenera, while the unifacial type is restricted to a few sections of the subgn. *Extrastaminalia*. Moreover when we except the species of § *Negundo* and § *Cissifolia*, seeing that they represent merely local unifacialities, the unifacial type is restricted mainly to § *Palmata* and § *Platanoidea*.¹⁾

D. Table showing vascular anatomical and external morphological features

Of the various vascular anatomical and external morphological features, several important ones are shown in a table (Tab. III) from which it is possible to see at a glance the characteristic features in each species and the close relationships that prevailing among species, sections and subgenera.

Tab. III.

Vascular anatomical features.

- Lg*: number of foliar gaps (cf. p. 31 sqq.).
- m*: a pair of bundles of median trace origin on the dorsal arc (cf. p. 32 sqq.). *l*, large; *s*, small; —, absent.
- VB*: the ventral bundle (cf. p. 33 sqq.). *M*, components derived only from the median foliar trace; *M(L)*, the same derived mostly from the median foliar trace and partly from the lateral traces (*a*, components from the lateral traces issue only from the original inner margin of the traces; *b*, the same from the lateral traces issue from each margin or from a few margins of divided bundles from the original lateral traces); *ML*, components derived from median and lateral foliar traces of almost the same size (*a*, same as the case of *M(L)-a*; *b*, same as the case of *M(L)-b*).

1) According to PENZIG (1921), in *A. platanoides*, an abnormal case in which the formation of the epiascidia takes place by fusion of margins of the lamina base was reported by PAX and DAMMER (1886)—a fact that seems to relate to the unifacial petiole in this species.

da: number of main bundles on the dorsal arc in the middle of the slender part of petiole (cf. p. 37 sqq.).

Med: formation of medullary bundles at the petiolar base (if present, they continue throughout the whole slender part) (cf. p. 48 sqq.). +, present; —, absent.

mpt: formation of the medullary bundles at the petiolar top (cf. p. 52 sqq.). +, formation takes place; —, does not take place.

mn: medullary bundles in the base of nerves or petiolules (cf. p. 55 sqq.). ++, present in all nerves or petiolules; +, present only in certain nerves or petiolules; —, altogether absent.

External morphological features.

Lt: leaf types. *pal-n*, palmately nerved; *pal-c*, palmately compound; *pin-n*, pinnately nerved; *pin-c*, pinnately compound.

n: number of main palmate nerves or petiolules (cf. p. 37 sqq.).

fa: face of petiole (cf. p. 59 sqq.). *B*, bifacial structure (*a*, ridges and groove conspicuous; *b*, cylindrical; *a-b*, form intermediate between *a* and *b*); *U*, unifacial structure (*a*, cylindrical; *b*, characterized by secondary ridges and groove; *a-b*, a form intermediate between *a* and *b*; *c*, characterized by local unifaciality).

Signs and numerals in parenthesis or bracket refer to rare cases.

Plants	Anatomical Features							External Morph. Features		
	Lg	da	m ₁	VB	Med	mpt	mn	Lt	n	fa
subgn. <i>Intrastaminalia</i>										
‡ 1. <i>A. parviflorum</i>	3	7-9	1	ML-b	+	—	++	pal-n	5	Bc
‡ 2. { <i>A. distylum</i> <i>A. cratægifolium</i>	3	7	1	ML-a	+	—	+	pal-n	5-7	Ba-b
	3	5	1	ML-a	—	—	—	pal-n	3	Ba
‡ 3. <i>A. carpinifolium</i>	3	9	s	ML-a	+	—	+	pin-n		Ba
‡ 4. { <i>A. rufinerve</i> <i>A. capillipes</i> <i>A. rubescens</i>	3	7	s	{ ^M [M(L)-a]	—	+	—	pal-n	5	Ba
	3	7	s	M	—	+	—	pal-n	5	Ba
	3	7	s	M	—	+	—	pal-n	5	Ba
‡ 5. { <i>A. micranthum</i> <i>A. Tschonoskii</i>	3	7	{ s —	{ ^M [M(L)-a]	—	+	—	pal-n	5	Ba
	3	7	s	{ ^M [M(L)-b] [M]	—	+	—	pal-n	5	Ba
‡ 6. <i>A. argutum</i>	3	7	{ [—] (s)	ML-a	—	+	—	pal-n	5	Ba

Plants	Anatomical Features							External Morph. Features		
	Lg	da	m ₁	VB	Med	mpt	mn	Lt	n	fa
subgn. <i>Extrastaminalia</i>										
§ 7. <i>A. negundo</i>	3	7-9	1	ML-b	+	+	++	pin-c	3-5	Uc
§ 8. <i>A. cissifolium</i>	3	5	1	ML-a	+	-	++	pal-c	3	Uc
§ 9. { <i>A. pycnatum</i> var. <i>rubrum</i> <i>A. dasycarpum</i>	3	5	s	{ ML-a [M(L)-a]	{ + (-)	-	{ ++ (-)	pal-n	3	Bc
	3	7-9	1	ML-a	+	-	++	pal-n	5	Bc
§ 10. { <i>A. aizense</i> <i>A. trifidum</i> <i>A. trifidum</i> var. <i>formosanum</i> <i>A. ukurunduense</i> <i>A. Oliverianum</i> var. <i>Nakaharæ</i> <i>A. pseudo-platanus</i>	3	5	1	ML-a	-	-	-	pal-n	3	Ba
	3	5	1	ML-a	-	{ - (+)	-	pal-n	3	Ba
	3	5	1	ML-a, b	-	{ + (-)	{ - (+, ++)	pal-n	3	Ba
	3	7-9	1	ML-(a),b	-	+	++	pal-n	5-7	Bb
	{ 3 4 5	7-9	s	ML-a, b	-	+	-	pal-n	5	Ub-c
	3	7-11	1	ML-b	+	+	++	pal-n	5	Ua-b
§ 11. { <i>A. amoenum</i> <i>A. ornatum</i> <i>A. ornatum</i> var. <i>Matsumuræ</i> <i>A. formosum</i> <i>A. Sieboldianum</i> <i>A. Sieboldianum</i> var. <i>microphyllum</i> <i>A. Shirasawanum</i> <i>A. tenuifolium</i> <i>A. japonicum</i> <i>A. Heyhachii</i>	3	9	-	{ M [M(L)-a]	-	+	-	pal-n	7	Ub-c
	3	9-11	s	M	-	+	-	pal-n	7-9	Ua-b
	3	9	s	M	-	+	-	pal-n	7-9	Ua
	3	7-9	s	M(L)-a	-	+	-	pal-n	5-7(9)	Ua
	3	7-11	s	{ M(L)-a [M]	-	+	-	pal-n	9(7)	Ua
	3	9-11	s	{ M(L)-a [M]	-	+	-	pal-n	9(7)	Ua
	3	11-13	s	{ M(L)-a [M]	-	+	-	pal-n	9-13	Ua
	3	7-9	s	M(L)-a	-	+	-	pal-n	9-11	Ua
	3	11-15	s	{ M(L)-a [M(L)-a] M	{ - (+)	+	{ - (+)	pal-n	11-13	Ua-b
	3	11-15	s	{ M(L)-a [M]	+	+	{ - (+)	pal-n	11-13	Ua-b
§ 12. { <i>A. oblongum</i> <i>A. lævigatum</i>	3	5(7, 9)	1	ML-a	-	+	++	pin-n		Bc
	3	5(7)	-	M(L)-a	-	-	-	pin-n		Ba
§ 13. <i>A. nikoense</i>	5	13-17	1	ML-b	-	+	++	pal-c	3	Bb
§ 14. <i>A. campestre</i>	3	7	1	ML-a	-	+	+	pal-n	5	Bc

Plants	Anatomical Features							External Morph. Features		
	Lg	da	m ₁	VB	Med	mpt	mn	Lt	n	fa
§ 15. <i>A. mono</i>										
§ 16. <i>A. diabolicum</i>										

III. Résumé

(1) The first part of this paper describes in detail the vascular systems in the nodal region, base, slender part and the top of the petiole, illustrated by 42 species belonging to 16 sections of *Acer*. The second part discusses generally the types of vascular systems and also certain important histological characters of the petiolar bundles, and deals with external morphology.

(2) The foliar gaps of a leaf are three in almost all species. In *A. nikoense*, however, five gaps are always observed, while in *A. Oliverianum* var. *Nakaharae* cases with three, four and five gaps are found. In every case a single foliar trace issues from each gap.

(3) The median trace sooner or later divides into three, and the lateral ones (outer ones when there are four or five gaps) into two bundles.

(4) Entering the petiolar base, foliar traces undergo further division, fusion, translocation, twisting, etc., resulting in the formation of the vascular circle in the slender part of the petiole. The vascular circle may be divided into the "dorsal arc", consisting of a certain number of separated bundles, and the "ventral bundle", usually consisting of a single large bundle situated on the chord of an arc.

(5) Of the bundles on the dorsal arc, the median and a pair of its neighbouring bundles, the size of which may be fairly large or small, or the bundles sometimes, though rarely, altogether absent, originate from the median foliar

trace, and the other lateral bundles from the lateral foliar traces. The size of a pair of bundles of the median origin are markedly alike in species of the same section. Although these bundles frequently fuse together with neighbouring lateral bundles at a certain lower height, the fusion is unstable, whence it may be said that the connection holding the original median and the lateral traces is rather weak.

(6) The manner in which the ventral bundle forms may roughly be divided into the following three types: (a) the components of the ventral bundle come only from the two margins of the median foliar trace (*M*-type), (b) most of those from the median trace arise with a small part that issues from the lateral traces (*M(L)*-type), and (c) the sizes of those from both median and lateral traces are almost alike (*ML*-type). Species belonging to one and the same section almost invariably represent the same type. Whereas the last type widely prevails, the former two are restricted to a few closely related sections.

(7) The relative positions between the dorsal arc and the ventral bundle may be ascribed to a few slightly differing conditions.

(8) Parallel correlation to a high degree exists between the number of main vascular bundles on the dorsal arc and that of palmate nerves or leaflets. Usually, the number of the former exceeds that of the latter by one or two pairs.

(9) At the petiolar top, the vascular circle for each palmate nerve or petiolule usually consists, at first, of six bundles (besides these there are often bundles derived from the medullary bundles, which however are not considered here), viz., the ventral three and dorsal three that are derived respectively from the ventral bundle and the dorsal arc. Soon, each lateral bundle of ventral three fuse together with the neighbouring laterals of the dorsal three to form a pair of large bundles, resulting in the formation of a vascular circle on which four bundles, a ventral, a dorsal and a pair of large laterals are arranged. However in the vascular circle that enters the outermost nerves or petiolules, the outer of these large lateral bundles is totally derived from the dorsal arc. Running up to a certain height along the nerves, the dorsal and both lateral bundles eventually fuse together and form a continuous arc. The distribution of the original foliar traces to the nerves or petiolules also deserves notice.

(10) The vascular bundles on the fundamental vascular system are usually of collateral structure. There are no peculiarities in their woody parts. In the phloem, however, are large or small sieve-tube groups and somewhat large parenchymatous and secretory elements. Their relative positions in the arrangement vary to a small extent, each of which, with certain exceptions, is represented by definite systematic groups.

(11) We have met with, though rarely in the species studied, with bundles of special structure, namely, amphivasal concentric, subcollateral, etc. These structures appear chiefly in bundles on the extremities of the dorsal arc.

(12) In most species, including about 93 per cent of the total number of species studied, the complicated vascular system is made more so by the presence of a medullary system. The way in which these bundles form may roughly be divided, taking into account of their presence or absence and the particular parts whence they have originated, into the following types. A. without medullary bundles in any part, and B. with them. The latter is subdivided into 1. no formation at the petiolar base, but at the petiolar top, and 2. at the petiolar base and running through the petiole up to its top. In the latter case *a.* no bundles are freshly formed at the top, and *b.* new bundles are added at the top. Of these cases, *B-1* and *B-2-b* are again divided into two respectively according to whether or not the medullary bundles remain in the vascular circles of nerves or petiolules.

(13) As to the prevalence and distribution of the above mentioned types, excepting rare cases, type *B-1* is most prevalent (30 species), while types *A* and *B-2* are comparatively rare, being respectively represented by 3 and 9 species. Species belonging to one and the same section mostly represent, though there are a few exceptions, the same or intimately allied conditions. This relationship also exists among a certain number of closely allied sections.

(14) The manner in which these bundles form and their course in the base and in the slender part and top of the petiole are described together with some of their interesting structures.

(15) The structure of petioles may be classified from the standpoint of external morphology into the following cases: The petioles in many species are characterized by bifacial structure throughout their whole length, and in others by unifacial structure throughout their whole length or, rarely, only at a certain lower height. Secondary ridges and groove are rarely seen in unifacial petioles. Accompanying the unifacial structure, a more or less shallow cavity for the intra-petiolar bud is formed in some species. Species belonging to one and the same section represent, with a few exceptions, the same structure. All sections of subgn. *Intrastaminalia* and many of subgn. *Extrastaminalia* are characterized by bifacial structure, while the unifacial structure is restricted to a few sections of subgn. *Extrastaminalia* (e. g., § *Palmata*, § *Platanoidea*, etc.).

(16) Although various types of vascular systems have been observed, they are quite independent of these external morphological features, and as far as

the present observations go, the characteristic features of the vascular system in connexion with unifacial and bifacial structures could scarcely be discerned. This relation between the vascular system and external morphological features seems to be worthy of notice, and manifestations of them should be looked for by investigators on numbers of other examples.

(17) Finally, some important features in external morphology and vascular systems are assembled in a table to enable comparison of the characteristic features with the degrees of close relationship that holds among the species, sections etc.

* * * *

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